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# Force Allocation Modeling In Support Of Contingency Operations - Demonstration Study

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This is a working draft document and should be treated accordingly. This document is unedited and unreviewed and contains preliminary results.

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Resource allocation issues beyond those at the operational level have never been an issue with regards to operations. Enough redundant capabilities have existed within the services that executing a contingency operation was not critically important in terms of resource allocation. However, the current resource constrained environment coupled with the increased commitment to contingency operations no longer allow long term strategic planners to ignore the effects on the services ability to execute the National Military Strategy. This research contained herein is focused on developing a methodology to incorporate contingency operations into the force design process. The research was solely a proof-of-principal demonstration.

As a first step in developing a resource allocation methodology, a framework was developed for assessing the effectiveness of units for both warfighting and nonwarfighting missions. Using this framework, theory for a deterministic mathematical program that could be solved for multiple scenarios was developed. The methodology presented herein is different from other mathematical programming approached for force allocation in that 1) the hierarchical scenario structure for assessing a unit's effectiveness and 2) the mathematical programming technique produces an optimal solution for more than one scenario which can be composed of a numerous missions.

Lastly, a proof-of proof demonstration is presented to show the utility of the methodology. Based on unclassified information, threat scenarios were developed for year 2005 (2 project objective memorandum or POM cycles). A demonstration study was conducted at the division, carrier battle group, and air force wing level of resolution. This level of resolution is too gross for a meaningful study; however, the results are important to show the utility of the approach.

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Dr. Alfonso A. Diaz was the Director of the SAC, OSDPA&E. Within OSDPA&E this work was part of the Operations Other Than War (OOTW) Analysis Project. Mr. Jerome Visser, SAC, was the study director at OSDPA&E. This report was written by Drs. Farr and Goldberg. The General Algebraic Modeling System (GAMS) implementation of the methodology was performed by Dr. Goldberg.

This bulk of this research was conducted during the period 1 Oct 1995 through 1 April 1996. The methodology and results contained herein are not to be construed as official Department of the Army (DA) or Department of Defense (DoD) position, policy, or decision. The methodology and results contained herein are solely the responsibility of the authors.

[1] During the period this research was conducted, Dr. Goldberg was a Visiting Professor, DSE, USMA.

# Executive Summary


Resource allocation issues beyond those at the operational level have never be an issue with regards to peace operations. Enough redundant capabilities have existed within the services that executing a contingency operation was not critically important in terms of resource allocation. However, the current resource constrained environment coupled with the increased commitment to contingency operations no longer allow long term strategic planners to ignore the effect on the services ability to execute the National Military Strategy. This research contained herein is focused on developing a methodology to incorporate contingency operations into the force design process. The research was solely a proof-of-principal demonstration.

As a first step in developing a resource allocation methodology, a framework was developed for assessing the effectiveness of units for both warfighting and nonwarfighting missions. Using this framework, theory for a deterministic mathematical program that could be solved for multiple scenarios was developed. The methodology presented herein is different from other mathematical programming approaches for force allocation in that

- the hierarchical scenario structure for assessing a unit's effectiveness and
- the mathematical programming technique produces an optimal solution for more than one scenario which can be composed of a numerous missions.

Lastly, a proof-of-principal demonstration is presented to show the utility of the methodology. Based on unclassified information, threat scenarios were developed for year 2005 (2 project objective memorandum or POM cycles). A demonstration study was conducted at the division, carrier battle group, and air force wing level of resolution. This level of resolution is too gross for a meaningful study; however, the results are important to show the utility of the approach.

# Table of Contents

# List of Tables



# List of Figures

# Force Allocation Modeling In Support of Contingency Operations - Demonstration Study

## 1.0 Introduction

### 1.1 Background

The Office of the Director, Program Analysis and Evaluation (ODPA&E), Theater Assessments and Planning, Simulation and Analysis Center (SAC), is conducting a major effort to assess the impacts of Operations Other Than War (OOTW) on resource allocation and planning within the Department of Defense (DoD). This OOTW Analysis Project has four principal objectives:

- to provide ODPA&E an improved capability to conduct efficient and effective analysis of the impact of OOTW on the DoD;
- to provide, in the near-term, specific Front End Analysis (FEA) of significant issues whose results can be used in the development of the next Defense Planning Guidance (DPG);
- to initiate a series of multinational contingency operations games which will provide insight into the conduct of OOTW and support the development of OOTW analytic tools; and
- to provide an enhanced analytical capability for ongoing SAC risk assessments.

The research documented herein is directed mainly towards objectives one and four. Other implied objectives include the ability to support the unified Commanders-In-Chief (CINCs) in planning and evaluating OOTW in their areas of responsibility and to develop guidance that can be used by the individual services in the long term development of defense planning.

The approach developed to meet the OOTW Analysis Project Plan Objectives includes military-political (MILPO) games and a family of analytical tools. Described herein are the results of an effort to establish one of these models that will comprise the OOTW modeling tool kit. This effort focused on a high level model to conduct force structure tradeoffs for a variety of warfighting and non-warfighting missions. Additionally, the model and associated methodology described will be used to assess the effects of

contingency operations on the total DoD force structure and will be here after referred to as the resource allocation model for contingency operations (RAMCO). The framework in which RAMCO and other models in the toolkit will operate are shown in Figure 1.1.

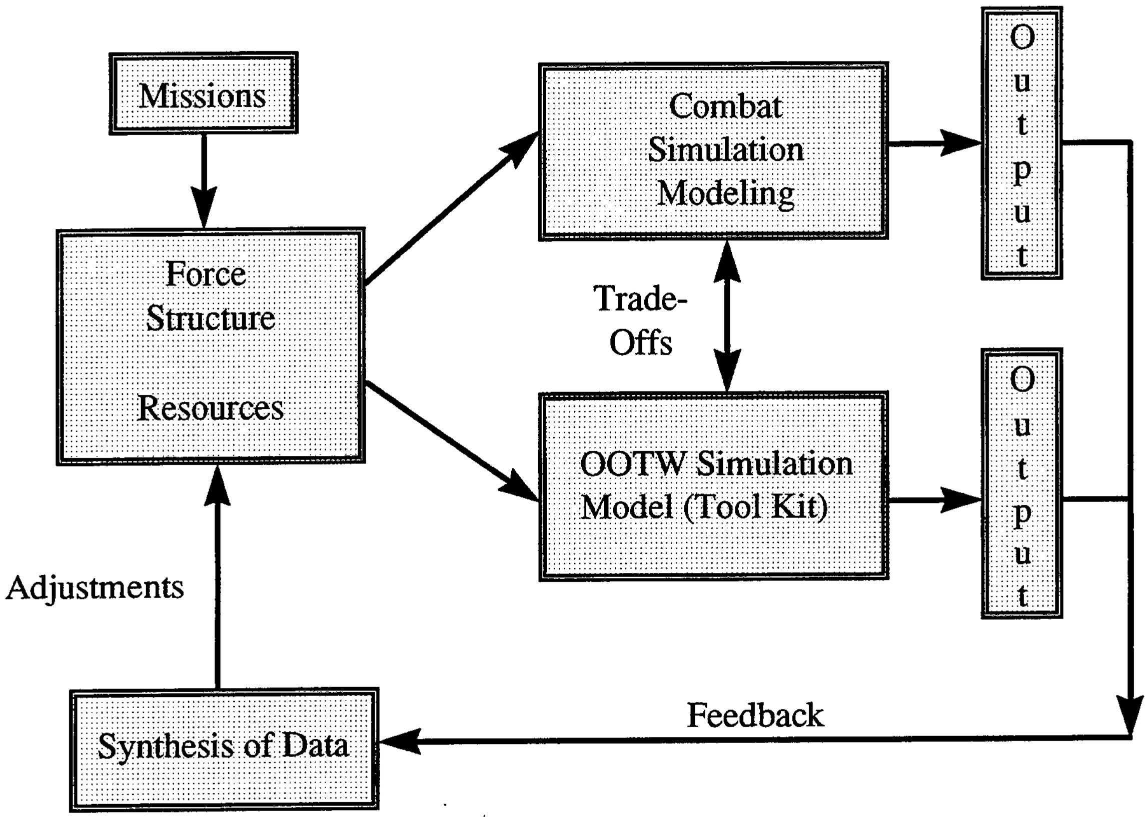


*Figure 1.1 Framework for resource allocation using the OOTW simulation model "toolkit"*

## 1.2 Definitions

One of the basic assumptions of the RAMCO model are that scenarios can be decomposed into missions. A *MISSION*, in its broadest sense, is defined as a request for major military support. A "major regional conflict or MRC" or a "clean-up after a natural disaster" are examples of potential missions. For every mission, we assume that a set of *TASKS* are known. The tasks represent the events that occur to ensure successful completion of the mission. More generally, since there may not be absolutes in missions, the "better" the tasks are completed, the more successful the mission. The term "better" might include;

faster, more lethal, fewer fatalities, lower cost, or a host of other objectives. Each task is assumed to be composed of a set of *ACTIONS* that must be done to complete the task. These actions can be dependent on each other and the level of their completion leads to the level of task completion. The three levels; actions => tasks => missions are shown in Figure 1.2. Also, we must know the relationships between each level so that we can measure the success of completing an item as a function of the success of performance of its predecessor items. Note that missions may share tasks and tasks may have common actions, so the decomposition is not necessarily treelike; however, by including repeat tasks and actions, it will become a Directed Acyclic Graph (DAG).

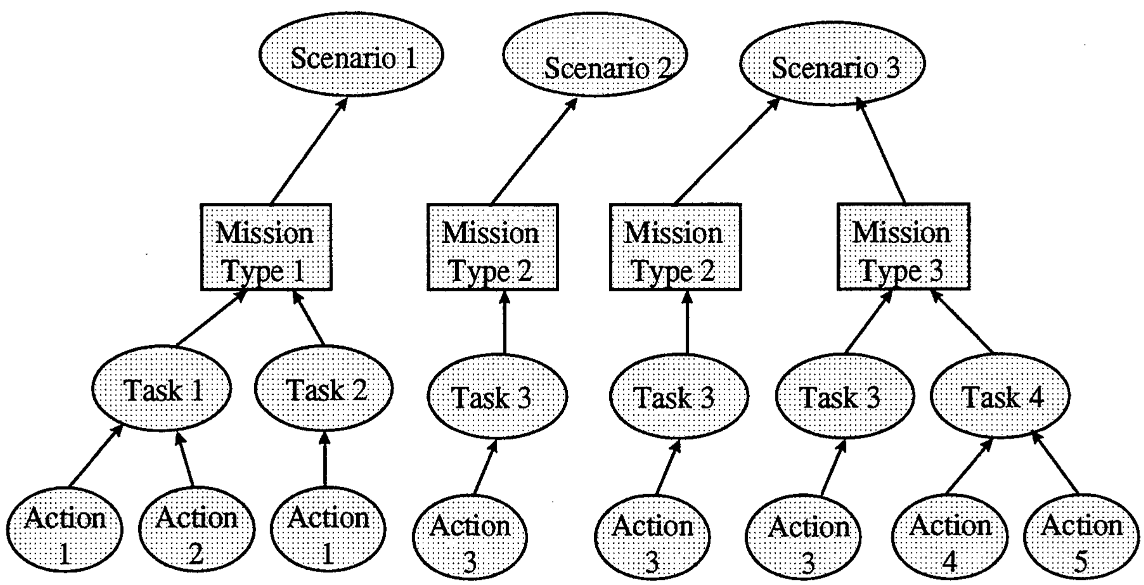


***Figure 1.2 Hierarchical scenario structure***

In addition to those already stated, the following definitions are presented. Unless noted otherwise, the terminology herein is not a DoD standard and may be applicable only in the context of this document.

<u>Counterdrug Operations</u> - Military efforts in this arena support and complement, rather than replace, the counterdrug efforts of other U.S. agencies, the states, and cooperating foreign governments. These efforts can include, but not be limited to, collaboration with host nation army forces to prevent export of

illegal drugs and nation assistance efforts to develop economic alternatives to production, exportation, and distribution of drugs.

Force Structure - Describes the formal organization of weapons, people, and equipment used by DoD to perform it's various missions and roles.

Humanitarian Assistance and Disaster Relief - Humanitarian assistance operations provide emergency relief to victims of man-made disasters when initiated in response to domestic, foreign government, or international agency requests for immediate help and rehabilitation. Disaster relief operations include activities such as refugee assistance, food programs, medical treatment and care, restoration of law and order, damage and capabilities assessment and damage control (e.g., environmental cleanup, fire fighting, etc.).

Insurgencies/Counterinsurgencies Support - U.S. military forces may assist either insurgent movements or host nation governments opposing an insurgency. The U.S. uses it military resources to provide support to a host nation's counterinsurgency operations in the context of foreign internal defense through logistical and training support.

Mathematical Programming - Mathematical modeling is concerned with the development of procedures for the purpose of maximizing the extent to which the goals of the decision maker are realized. Typically, this is accomplished by representing non-mathematical reality by means of equations and other mathematical statements. Solution techniques usually involve matrix algebra techniques.

Nation Assistance - Nation assistance supports a host nation's effort to promote development (ideally) through the use of host nation resources. Nation assistance typically involves vertical and horizontal construction missions. The goals of nation assistance are to promote long term stability, develop sound and responsive democratic institutions, develop supportive infrastructure, promote strong free-market economies, and provide an environment that allows for orderly political change and economic progress.

Peace Enforcement - Peace enforcement operations are military operations in support of diplomatic efforts to restore peace between hostile factions which may not be consenting to intervention and may be engaged in combat activities. Peace enforcement implies the use of force or its threat to coerce hostile factions to cease and desist from violent actions.

Peacekeeping Operations - Peacekeeping operations support diplomatic efforts to maintain peace in areas of potential conflict. The U.S. may participate in peacekeeping operations when requested by the United Nations (UN), with a regional affiliation of nations, with other unaffiliated countries, or unilaterally.

US personnel may function as impartial observers, as part of an international peacekeeping force, or in a supervisory and assistance role.

Roles and Missions - Operational roles and tasks performed by the DoD as designated by the President or Secretary of Defense.

Shows of Force - A show of force is a mission carried out to demonstrate U.S. resolve in which U.S. forces deploy to defuse a situation that may be detrimental to US interests or national objectives. They can take the form of combined training exercises, rehearsals, forward deployment of military forces, or the introduction and buildup of military forces in a region.

WEI/WUV (weapon effectiveness index, weighted unit value) - A subjective force or weapons scoring methodology.

## 1.3 Scope

This report contains five chapters. Chapter 1 contains background information. Chapter 2 presents an overview of the force design process and how OOTW should influence the process. Chapter 3 presents the methodology developed for assessing joint force structure for various roles and missions with emphasis on contingency operation. Chapter 4 contains an example study used to demonstrate the methodology. The study presented in this chapter was performed only for proof of principal. Lastly, Chapter 5 contains the summary and conclusions section. The report contains two appendices. Appendix A contains a listing of all acronyms and abbreviations used in the report. Appendix B contains information relevant to example problem and the software implementation of the methodology.

# 2.0 Overview of Operations Other Than War Analysis

## 2.1 Introduction

The individual services design forces from an operational perspective. The traditional role of the military is to successfully complete wartime missions important to the nation. Missions other than those specified as traditional warfighting, such as participation in multinational peacekeeping operations, are considered secondary roles and produce derived benefits. In an era of downsizing and the elimination of redundant capabilities, the risk of executing a MRC and supporting commitments for OOTW throughout the world must be closely scrutinized. This analysis is especially critical since the execution of these OOTW missions is not presently considered in the total force design process.

Since the ending of the cold war, the implications for contingency operations with regards to force design are enormous. The OOTW mission has emerged as a major challenge from a tactical and planning perspective and an operational perspective. OOTW is no longer an Army specific mission; but must be analyzed from a joint service perspective to ascertain the effects on other high priority missions within the National Military Strategy. Some specific issues that should be considered are

- What are the effects on a MRC when propositioned equipment has been diverted for a contingency operation?
- With regards to resource allocation, what planning factors need to be considered to reduce the risk of successfully conducting an MRC while conducting a simultaneous major contingency operation?
- What factors must be considered by the CINC to minimize the impact of reconstitution of unit participating in a simultaneous contingency operations being assigned to a MRC?
- What force structure implications (guard, reserve, active components) have to be considered to ensure the service forces are robust enough to respond to these contingency operations and still be able to fulfill the requirements to fight and win two simultaneous MRCs?

Beyond these major issues, many smaller subordinate issues exist that are too numerous to discuss. However, the important observation is that resource

allocation is much more complex than at any time in history because of the diversity of the roles and missions of the services. As a results new analytical techniques must be developed to study these problems.

## 2.2 Resource Allocation Methodology For Contingency Operations

Enough redundant capabilities have existed within the services that executing a contingency operation was not as issue. Therefore, resource allocation issues beyond those at the operational level have never be an issue with regards to peace operations. However, the resource constrained environment coupled with the increase commitment to contingency operations no longer allow long term strategic planners to ignore the effect on the services ability to execute the National Military Strategy[1]. This research is focused on developing a methodology to include major contingency operations as part of the force design process.

[1] The current Bosnia operation has 15 peacekeepers per 1000 inhabitants!

# 3.0 Resource Allocation Methodology For Contingency Operations (RAMCO) Model

## 3.1 Introduction

Numerous methodologies exist or can easily be modified to conduct resource allocation. Once the objectives have been clearly established (maximize combat capabilities, minimize cost, etc.,), the scenarios described ( 1MRC with a major peace operations commitment, 2 simultaneous MRCs, etc.,), and the measures of success defined (minimal blue losses, smallest time to completion of the event, etc.), numerous techniques can be used to ascertain whether a force mix can accomplish the mission. Unfortunately, with the exception of some limited analysis by the joint staff, most force design is service dependent. In addition, the force design process is not affected by contingency operations. Simulation is the primary assessment tool. Unfortunately, simulation does not provide an optimal solution - just an evaluation of the current system. A technique that provides an optimal solution, allows for joint force analysis, and accounts for contingency operations is needed. The RAMCO model was developed to meet this need and is described in subsequent sections.

## 3.2 General Methodology

A force is sent to complete a mission. The force is composed of *UNITS*, our basic building block. A unit may have manpower, weaponry, and support associated with it, and its size depends on the level of detail in the study. For each unit, its ability to perform *actions* must be determined and measured on an appropriate scale. We assume that this action performance ability is deterministic, that data such as the cost and maximum number of units available are known, and that the units can be combined seamlessly with both the same and different types of units.

We now have enough detail to specify the problem. Assume that we have a set of scenarios that are composed of missions. A mission may be contained in multiple scenarios and the scenarios are mutually exclusive and exhaustive: that is, we assume exactly one will occur. The key idea in the RAMCO model is that the force structure must be such that each scenario can be completed, regardless of what scenario occurs. Therefore, we must design a force that meets the action requirements of all scenarios at the lowest possible system cost. We note that system cost is only one of many possible measures of effectiveness (MOE's) for the force design.

The critical issues in implementing a force structuring model are determining the family of missions and how they can fit into appropriate scenarios, determining the appropriate level of detail of the units (for example, should we use brigade or division sized units), estimating the values for unit cost, estimating the amount of action that each unit can provide for a mission task, estimating the amount of each action required for successful completion of each mission task, and constructing relationships of how combining units and their actions aids in the completion of mission tasks. Figure 3.1 represents a process of how we anticipate estimating the required data and how the data fits into the modeling process. At this time, we have finished a first cut force structure model and have started on the data and function estimation process for the peacetime missions. We have not started on the data and function estimation for the wartime missions, however we have a process that uses results from operational simulations to estimate the required information. We leave this implementation to future work since we do not presently have access to the required simulation model and input data.

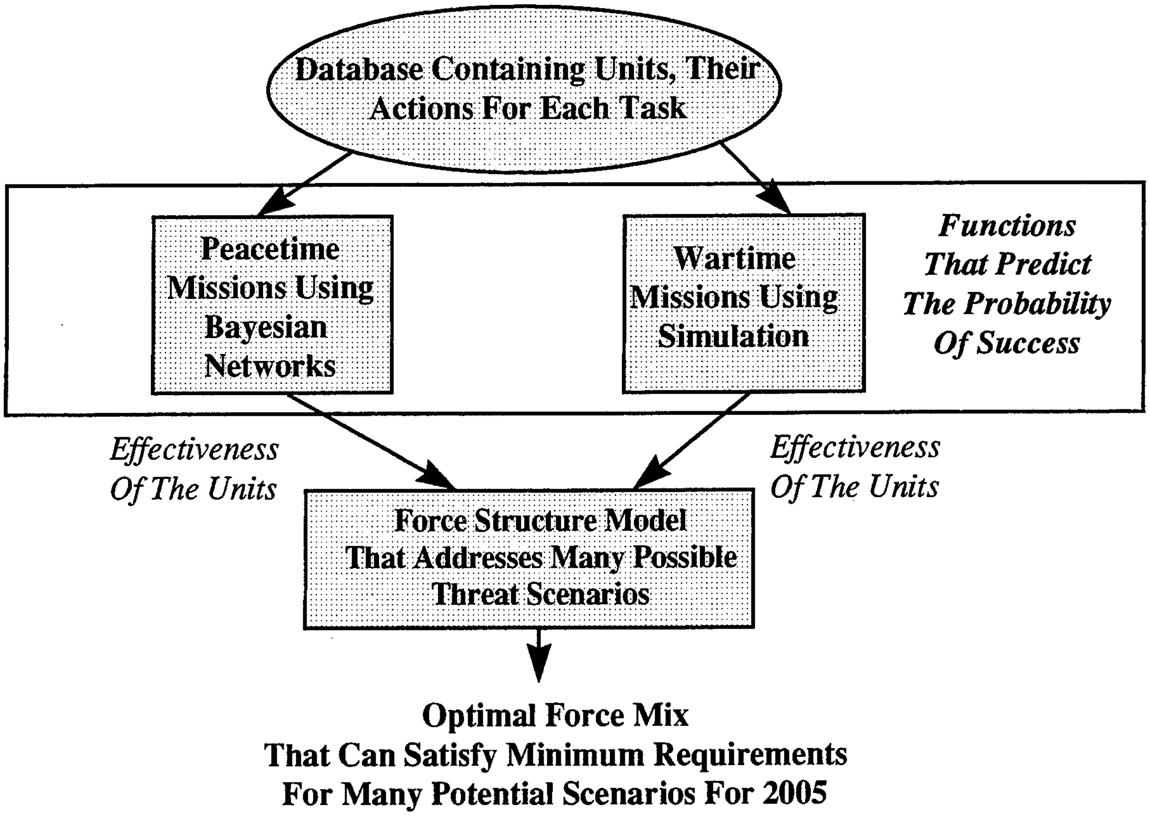


*Figure 3.1 Overview of force allocation modeling methodology*

To describe the mission-task-action and unit structures in real terms, consider a force that uses the DoD active duty baseline force (10 Army Divisions, 3 Marine Divisions, 11 Carrier Battle Groups, and 20 Air Force Wings). A futuristic group of scenarios projected to 2010 (14 years or 2 POM cycles) might be composed of the following simultaneous missions:

- 1 MRC (US Attacking Force) in Southwest Asia,
- 1 lesser regional conflict in Central America,
- 2 major nation assistance missions in Africa,
- 1 peace enforcement mission in Central Europe,
- 1 peace keeping mission in North Africa, and
- 1 show of force mission in Southeast Asia.

In addition to describing the tasks, a quantifiable value must be assigned to a unit's ability to provide actions to conduct a task. Some examples of tasks for the major regional conflict might include conducting

- a major sea training exercise,
- a major amphibious landing training exercise,
- a dismounted training exercise,
- an air-to-air training exercise,
- conduct close air,
- conduct dismounted infantry warfare,
- conduct mounted warfare,
- obtain and maintain air superiority, etc.

Task information (i.e., support or capabilities) must be obtained for each of these tasks. This can be obtained from the force structure analysis conducted by the SAC in support of the two MRC contingency analysis. Note that tasks can often be conducted by various types of units at different levels of effectiveness. For example, all four services maintain their own close air support (CAS) capability. Multiple combinations of units are available to conduct a mission.

Though simpler, obtaining the non-warfighting missions will be more difficult because of the lack of previous studies. A typical peace enforcement operation might include the following tasks:

- enforcement of sanctions,
- protection of humanitarian assistance, and
- forcible separation of belligerents.

Lastly, actions are needed to perform tasks. For example, the ability to conduct ground warfare against mounted units might require conducting the following actions

- anti submarine operations,
- anti surface operations,
- attack air,
- deep attack,
- ground combat against mounted units,
- electronic warfare air,
- theater ballistic missile defense, etc.

Note that actions are not required to define missions, however, actions can be used to provide a means for developing a quantifiable measure of a unit's ability to aid in the completion of the task.

In the remainder of the chapter, we discuss the models developed and potential methods for determining the unit-action abilities and the action requirements for tasks.

## 3.3 Force Structure Models

We believe that the force structure model takes the following data as inputs;

- the scenarios - occurrence probabilities, importance factors, included missions, and functions to predict success for the scenario as a function of mission success;
- the missions - included tasks, and the probability of successful completion (or other measure of effectiveness) as a function of the completion of the tasks;
- the tasks - included actions, and probability of successful completion (or other measure of effectiveness) as a function of the total amount of action from all units assigned to the task; and
- the units - number available and cost of each type, amount of each action that the unit is capable of providing.

In the remainder of this section, we discuss two approaches for finding force structures. The first approach extends work by Farr, Nelson and Diaz (1995) and models the decision problem as a deterministic linear integer programming model. We present a basic model and extensions to make the model include more features of the actual problem. The demonstration of

concept discussed in Chapter 4 uses this basic model. The second approach blends the stochastic scenario analysis method of Laferriere (1992) and the game theoretic shadow price evaluation strategy of Robinson (1993) into a model that allocates forces in a dynamic competitive environment. The approach is still under development and S. Robinson is preparing a technical report containing theoretical and computational results. Here we will give sufficient detail so that the key features and difficulties of the approach are evident.

### 3.3.1 Deterministic Mathematical Programming Model

To start, we consider a single scenario with a single time period (one force design) and the following assumptions:

- Units are assigned to missions directly; a commander may split a unit among different tasks if necessary;
- There is no organization structure that precludes selecting any unit to be assigned to any task.
- The actions of all units assigned to a task are additive (no synergy).
- Each task-action pair has a completion requirement that is the minimum amount of action strength that must be assigned to the task.

Define the following notation:

- $x_{um}$ = number of units of type $u$ assigned to mission $m$ (decision variable)
- $q_{autm}$ = amount of action $a$ accomplished for each unit of type $u$ assigned to task $t$ in mission $m$
- $R_{atm}$ = minimum requirement of action $a$ in task $t$ for mission $m$
- $Cap_u$ = total number of units of type $u$ available for assignment
- $C_u$ = cost for each unit $u$ deployed

The model to minimize the cost of satisfying all missions is:

$$\text{Minimize} \quad \sum_{m} \sum_{u} C_u x_{um} \tag{3.1}$$

$$\text{Subject to:} \quad \sum_{u} q_{autm} x_{um} \geq \sum_{t} R_{atm} \quad \text{for each } (a, m) \text{ pair} \tag{3.2}$$

$$\sum_m x_{um} \leq Cap_u \qquad \text{for each unit } u \tag{3.3}$$

$$x_{um} \geq 0 \text{ integer} \quad \text{for each } (u, m) \text{ pair} \tag{3.4}$$

(3.1) represents the objective of minimizing system cost. We multiply the cost per unit by the number of units needed and sum over all units. Constraint set (3.2) ensures that we have enough action strength for each action-mission pair. Here, we multiply the number of each unit type assigned to each mission by the amount of each action that the unit can perform. We then sum over all unit types (additivity and no synergy assumptions) and require that the sum be greater than the sum of the action requirements for each task in the mission (commander can allocate units to tasks as long as enough are assigned to a mission). Constraint set (3.3) ensures that across all missions, we do not assign more units than are available. Finally constraint set (3.4) limits the decisions to be nonnegative integers.

To extend the model to multiple scenarios we assume that the scenarios are mutually exclusive and exhaustive and hence one and only one scenario must occur. We must design the force to ensure that no mater what scenario occurs, we have sufficient resources to complete all missions. Using the notation for the single scenario model, we must modify the assignment decision variable to include a subscript for "scenario *s*", include requirements constraints for each action in each mission in each scenario, and ensure that each unit fielded is allocated at most one time in each scenario.

Define the following notation:

- $x_{usm}$ = number of units of type $u$ assigned to mission $m$ *in* scenario $s$ (decision variable)
- $X_u$ = number of unit $u$ deployed in the system (decision variable)
- $q_{autsm}$ = amount of action $a$ accomplished for each unit of type $u$ assigned to task $t$ in mission $m$, scenario $s$
- $R_{atsm}$ = minimum requirement of action $a$ in task $t$ for mission $m$, scenario $s$

- $Cap_u$ = total number of units of type $u$ available for assignment
- $C_u$ = cost for each unit $u$ deployed

The model to minimize the cost of satisfying all scenarios is:

$$\text{Minimize} \qquad \sum_{s}\sum_{m}\sum_{u} C_u X_u \qquad (3.5)$$

$$\text{Subject to:} \quad \sum_{u} q_{autsm} x_{usm} \geq \sum_{t} R_{atsm} \quad \text{for each } (a, s, m) \text{ triple} \qquad (3.6)$$

$$\sum_{m} x_{usm} \leq X_u \quad \text{for each } (u, s) \text{ pair} \qquad (3.7)$$

$$X_u \leq Cap_u \quad \text{for each } u \qquad (3.8)$$

$$X_u \geq 0 \quad \text{for each } u, \quad x_{usm} \geq 0 \text{ integer} \quad \text{for each } (u, s, m) \text{ triple} \qquad (3.9)$$

(3.5) represents the objective of minimizing system cost. We multiply the cost per unit by the number of units needed and sum over all units. Constraint set (3.6) ensures that we have enough action strength for each action-mission-scenario triple. Here, we multiply the number of each unit type assigned to each mission in each scenario by the amount of each action that the unit can perform. We then sum over all unit types (additivity and no synergy assumptions) and require that the sum be greater than the sum of the action requirements for each task in the mission (commander can allocate units to tasks as long as enough are assigned to a mission). Constraint set (3.7) ensures that across all missions in each scenario, we do not assign more units than we have purchased. Constraint set (3.8) ensures that we do not purchase more units than are available. Finally constraint set (3.9) limits the decisions to be nonnegative integers. The models described in Section 3.3 are all linear integer programming models. A basic assumption is that the actions of the units are additive and hence no synergy between units exists. Also, the models only consider a single decision period. Therefore units can only be assigned to a single mission, the missions have a single requirements value for each action, and each mission occurs over the entire period.

To extend the model to include synergy, we must develop a more general function to predict mission success. The Bayesian network approach can generate such functions for the OOTW tasks (and missions), however no similar method exists for the warfighting tasks. In any case, even if the functions can be developed, model solution may become extremely difficult since the functions may not be convex, continuous, and/or differentiable.

Extending the model to multiple periods is more realistic and considers interesting issues from the actual problem. Assume that the single time period modeled is broken down into T disjoint intervals. For each mission, we know the time intervals during which the mission occurs its location, and the amount of each action required during each time interval. Note that varying levels of mission intensity are possible under a multi-period framework. For each unit, we know its initial strength and its fielding cost. Now, the model must decide how to assign units to missions during each time period. Interesting modeling issues include:

- Units may degrade over time based on their assignment (this can easily be modeled as long as the degradation can be estimated).
- Units can be transferred between missions (either wholly or in part and with some cost) as missions become more and less intense.
- A target unit strength can be set for the termination of the scenario.
- The objective could be to minimize the sum of the unit fielding cost and the inter-mission unit transfer cost.

We believe that the extension to multiple periods also enables the inclusion of stochastic issues such as the location of missions, whether or not certain missions occur, and where in the horizon are missions most intense when they occur. Although we have not detailed the specifics of the model, there is evidence that the structure of the model remains linear, and hence there is a strong hope of solution either through specialized algorithms or general solvers (such as GAMS used in Chapter 4).

### 3.3.2 Dynamic Scenario Analysis

Dynamic scenario analysis (DSA) combines two model types into a single model. The first type is deterministic and finds either an optimal solution (when the model is a mathematical program) or an equilibrium point (when the model is a game). We note that this deterministic model can be used to find optimal decisions, or to find shadow prices for resource constraints (the model in 3.3.1 with multiple periods included is an example of the first type of model). The second model type in the DSA process has the structure of a probabilistic time-discounted Markov decision process. That is, the model's structure centers around a finite state space, an infinite set of discrete time stages and a set of time stationary probability distributions that describe the transitions between states at any time $t$. The distributions may depend on the actions taken, but that is not necessary for this discussion.

To put the above discussion in concrete terms, consider a mission over time. The deterministic model first finds the optimal force structure subject to constraints for minimum strength requirements, unit availability, and unit compatibility. The Markov decision process consists of how to allocate the force to satisfy the mission over the entire time horizon. States of the process might include the amounts of each unit's strengths remaining, unit location, and the enemy's strengths. Once a decision is made, a stochastic process governs how the state changes (i.e., how each unit is affected and how the enemy is affected) for the next time period and we again perform a decision analysis from the new state.

By using the appropriate deterministic and stochastic sub-models, DSA can incorporate both red and blue decisions, stochastic events, and dynamic decision making. At time 0, both sides determine their force structures, and then as time evolves, each side determines tactics to maximize their objective functions. We consider time discounting to ensure that the initial force structure is driven by critical costs depending on the magnitude of the discount factor.

The mathematical details of the method will be reported by Robinson and Lee (Ph.D. student at the University of Wisconsin-Madison) in a technical report scheduled for completion in August 1996. At this point, the model can be formulated and requires data similar to the deterministic models presented in section 3.3.1 and additional data to model the stochastic process governing state changes. Solution is also difficult, but progress has been made for specific forms of the framework and has been implemented in GAMS.

## 3.4 Data Estimation

The demonstration contained in Chapter 4 uses the multi-scenario model with 2 scenarios, 5 missions, 15 tasks, 55 actions, and 15 unit types. We use nominal data values for the action requirements and the unit-action abilities. To implement the RAMCO methodology on an actual situation, however, we need methods to estimate the coefficients (or more generally the functions) that relate the units assigned to a mission to task and mission success. Note that we must do this estimation, regardless of whether we use mathematical programming or the DSA approach. Two data estimation methods are described in the following subsections; one for OOTW missions and another for warfighting missions.

### 3.4.1 Method for Estimation of Values for Peacetime Missions

Our first step in determining the ability of units to perform tasks is to focus on the tasks required for the completion of three types of OOTW missions: humanitarian assistance (HA), peace enforcement (PE), and peacekeeping missions (PM). Other non-warfighting missions (show of force, nation assistance, disaster relief, etc.) have not been addressed in the initial phase of this work because of time and resource constraints, their secondary importance (in terms of resource requirements) to the missions stated above, and the need to ensure that the methodology works before generalization of the methodology. At the start of the project, George Mason University (GMU) had a computer database containing information on the above three types of missions, and their

associated tasks. It remained to break the tasks into actions and to model the effectiveness in task completion as a function of the action levels of units assigned to the task.

The approach centers around the use of Bayesian Networks to model the tasks for OOTW missions. In the approach, we construct a network structure that depicts the dependence relationships among the actions and the relationships of the actions with the task success MOE. Given the network and a method to measure the "amount" of each action in units assigned to the task, software exists to estimate a specific task MOE. The Bayesian Network construction enables the development of an easily evaluated function to measure the MOE as a function of assigned unit action and this function can be used as a constraint in the development of the force selection model.

Once the tasks are evaluated, then we can develop a method to evaluate mission MOE's. At this point, we are considering a Bayesian Network approach using the tasks, their computed MOE's, and their dependence relationships. Another alternative would be simply to call the mission successful as long as all tasks have a sufficiently large MOE's. The technical details of the approach will be reported by David Davis in a future technical report (under the UNYSIS cover).

### 3.4.2 Method for Estimation of Values for Warfighting Missions

As an initial starting point, the database containing HA, PK, and PM tasks contains the same task breakdown missions in lesser regional conflicts. We anticipate that this information can be expanded to identify those tasks necessary to conduct an MRC. Once the MRC tasks are set, the problem of modeling a unit's effectiveness in each of these tasks has been previously addressed by using a large joint combat simulation model. The underlying idea is to design a simulation experiment that individually varies the strength of each unit and computes the effect on the task MOE. The marginal effectiveness of a unit is basically the change in the MOE value for each additional strength unit tested.

Note that these changes are not constant and may be highly nonlinear as we increase the strength of the unit. Also, the approach generally requires a substantial number of simulation runs to evaluate the effectiveness of all units for all tasks. Therefore, a front end design of experiments is critical to efficiently and accurately estimate the data. Also, a subjective assessment of capabilities to focus on a small number of MOEs for each unit will be helpful to reduce the computations required.

For this approach to be successful the project team needs access to suitable simulation models and to the personnel and computer resources necessary to make the required classified simulation runs. Because of classification requirements, these resources will presumably have to be supplied by or through SAC.

Note that the use of units and assessing appropriate measures of effectiveness for both wartime and OOTW missions has numerous advantages over a weighted effectiveness index/weighted unit value (WEI/WUV) proposed by Farr et al (1995) in that

- it's logically defensible,
- it takes uncertainty into account in a genuine and transparent way, and
- force performance information can be computed using simulation models.

The challenge is in defining a realistic number of missions, scoping the number of units, and computing the necessary measures of effectiveness.

# 4.0 Demonstration Study

To demonstrate the RAMCO methodology, we constructed a 2 scenario case study. Our purpose here is to show that the models in Chapter 3 can be formulated and solved, if the data can be obtained. Our strategy was to use nominal values for the unit-action abilities and the requirements for actions in mission tasks. We conclude the chapter with insights into how the models and their solutions can be used in force structure decision making.

## 4.1 Introduction

The scenarios described below are based upon global security forecasts of major conflict environments that could occur between 2003 and 2013 (unclassified briefing material developed by the Army's National Ground Intelligence Center). The first scenario (see Table 4.1) is designed to be ground combat intensive. The second scenario (see Table 4.2) is designed to be more of a sea and air intensive scenario.

| Mission | Area |
|---|---|
| Show Of Force | China In The Spratlys |
| Major Regional Conflict | Iraq Versus Kuwait/Saudi Arabia |
| Major Non UN Peace Enforcement | Serbia Versus Albania |

***Table 4.1 Missions for the Land Intense Scenario (Scenario 1)***

| Mission | Area |
|---|---|
| Show Of Force/Security of Sea Lanes | Persian Gulf |
| Major Regional Conflict | China Versus Japan |
| Major Non UN Peace Enforcement | Hungary Versus Romania |

***Table 4.2 Missions for the Air and Sea Intense Scenario (Scenario 2)***

One of the issues concerning the methodology is the level of resolution needed to conduct a meaningful study. Typically, many OOTW tasks are conducted at the Army company level or smaller. In some instances, such as water purification, requirements are described at the individual piece of equipment

level. However, this is too fine a resolution because of the data requirements for a joint force structuring study. We anticipate that the desired level of detail should be

- Army and Marines - battalion
- Navy - individual ship
- Air Force - squadron

however if the data collection process becomes overbearing, we may need to increase the level of aggregation.

## 4.2 Study Results

For this sample study we used the fifteen units from all Services shown in Table 4.3. This is too coarse a level of for a meaningful study, however, to demonstrate the methodology these unit types are suitable.

| Units For Demonstration Study |
|---|
| Airborne Division |
| Light Infantry Division |
| Armored Cavalry Regiment |
| Marine Expeditionary Force |
| Air Assault Division |
| Heavy Division |
| Carrier Battle Group |
| Forward Deployable Aircraft Wing |
| Surface Action Group |
| Special Operating Forces |
| Submarines |
| Heavy Bomber Wing |
| Recon, Intel, Elect War Wing |
| Mine Warfare |
| Anti Sub Aircraft |

***Table 4.3 Units used for demonstration study***

The missions, tasks, and actions for the two scenarios are shown in Tables 4.4 and 4.5 for the missions described in Tables 4.1 and 4.2, respectively. Note that the mission effectiveness values represent each unit's ability to perform actions and along with the structure of the tasks and actions, were based on subjective judgment. These values were used only for the proof of principal demonstration of the methodology and exercising the RAMCO model. Additional data needed for input for the model is contained in Table 4.6. Model results are shown in Table 4.7 and Appendix B contains the GAMS implementation of the methodology.

In developing the scenarios and executing the methodology, some interesting insights were gained from the test data set. For example, we found that the model solution was highly sensitive to unit costs and task action requirements, and less sensitive to changes in unit action effectiveness values. The model has the ability to select a mix of units that achieves the mission requirements in a manner that is not transparent, even to an expert. From the sample study we can conclude that developing accurate cost data and scenario requirements will be critical to obtain meaningful results. A detailed study of the classical mathematical programming output is needed to better ascertain the importance of the accuracy of the unit-action data.

| MTA | Description | Mission Effectiveness Values | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mission 1** | **Show Of Force, China In The Spratlys** | AA | LID | ACR | MEF | ASD | HD | CBG | FDA | SAG | SOF | SUB | HBW | RIEW | MW | AS | Needed |
| Task 1.1 | conduct of a major sea training exercise | | | | | | | | | | | | | | | | |
| Action 1.1.1 | conduct anti submarine operations | 0 | 0 | 0 | 0.05 | 0 | 0 | 0.8 | 0 | 0.7 | 0 | 0.6 | 0 | 0 | 0 | 1 | 1 |
| Action 1.1.2 | conduct anti surface operations | 0 | 0 | 0 | 0.05 | 0 | 0 | 1 | 0 | 0.8 | 0 | 0.1 | 0 | 0 | 0.8 | 0 | 0.3 |
| Action 1.1.3 | conduct anti air operations | 0 | 0 | 0 | 0.2 | 0 | 0 | 1 | 0.5 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 |
| Action 1.1.4 | conduct surface operations | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 |
| Action 1.1.5 | conduct attack air operations | 0 | 0 | 0 | 0.2 | 0 | 0 | 1 | 0.5 | 0.2 | 0 | 0 | 0.3 | 0.2 | 0 | 0 | 0.3 |
| Task 1.2 | conduct major amphibious landing training exercise | | | | | | | | | | | | | | | | |
| Action 1.2.1 | conduct antisubmarine operations | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 1.2.2 | conduct anti surface operations | 0 | 0 | 0 | 0.6 | 0 | 0 | 1 | 0.5 | 0.5 | 0 | 0.5 | 0.2 | 0 | 0 | 0 | 0.3 |
| Action 1.2.3 | conduct anti air operations | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 | 0.7 | 0.8 | 0.4 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.3 |
| Action 1.2.4 | conduct surface operations | 0 | 0 | 0 | 1 | 0 | 0 | 0.6 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 |
| Action 1.2.5 | conduct attack air operations | 0.1 | 0.1 | 0.2 | 0.4 | 0.4 | 0.2 | 0.6 | 0.8 | 0.1 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0.3 |
| Action 1.2.6 | conduct close air support (CAS) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.3 |
| Action 1.2.7 | conduct ground combat against mounted units | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Action 1.2.8 | conduct ground combat against dismounted units | 0.2 | 1 | 0.4 | 0.4 | 0.6 | 0.6 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.4 |
| Task 1.3 | conduct of a dismounted infantry training exercise | | | | | | | | | | | | | | | | |
| Action 1.3.1 | conduct close air support (CAS) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.1 |
| Action 1.3.2 | conduct dismounted ground combat against mounted units | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| Action 1.3.3 | conduct dismounted ground combat against dismounted units | 0.2 | 1 | 0.4 | 0.4 | 0.6 | 0.6 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| Action 1.3.4 | maintain air superiority | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.4 | 1 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.1 |
| Action 1.3.5 | theater ballistic missile defense | 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 1 | 0.2 | 0.1 | 0.2 | 0 | 0.05 | 0.1 | 0.1 | 0 | 0 | 0.1 |
| Action 1.3.6 | electronic warfare ground | 0.4 | 0.2 | 0.2 | 0.4 | 0.4 | 1 | 0.2 | 0.2 | 0.2 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0.1 |
| Task 1.4 | conduct of a major air to air combat training exercise | | | | | | | | | | | | | | | | |
| Action 1.4.1 | maintain air superiority | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.4 | 1 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.1 |
| Action 1.4.2 | electronic warfare air | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.2 | 0 | 0.1 | 0 | 0 | 0 | 1 | 0 | 0 | 0.1 |

*Table 4.4 Scenario 1 - Mission, tasks, and actions and mission effectiveness values*

| MTA | Description | Mission Effectiveness Values | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mission 2 | Major Regional Conflict, Iraq Versus Kuwait/Saudi Arabia | AA | LID | ACR | MEF | ASD | HD | CBG | FDA | SAG | SOF | SUB | HBW | RIEW | MW | ASF | Needed |
| Task 2.1 | conduct close air support (CAS) | | | | | | | | | | | | | | | | |
| Action 2.1.1 | maintain air superiority | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 1 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| Action 2.1.2 | electronic warfare | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0 | 0 | 0.1 | 1 | 0 | 0 | 2 |
| Action 2.1.3 | deep attack | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.2 | 0.2 | 0 | 0.2 | 0.7 | 0 | 0 | 0 | 1 |
| Task 2.2 | conduct of dismounted infantry warfare | | | | | | | | | | | | | | | | |
| Action 2.2.1 | conduct ground combat against mounted units | 0.2 | 1 | 0.4 | 0.4 | 0.4 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 6 |
| Action 2.2.2 | conduct ground combat against dismounted units | 0.4 | 1 | 0.6 | 0.7 | 0.5 | 0.4 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 6 |
| Task 2.3 | conduct of mounted warfare | | | | | | | | | | | | | | | | |
| Action 2.3.1 | conduct mounted combat against mounted units | 0.2 | 0.2 | 0.6 | 0.6 | 0.3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Action 2.3.2 | conduct mounted combat against dismounted units | 0.3 | 0.3 | 0.7 | 0.7 | 0.5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Task 2.4 | conduct strategic attacks against hardened targets | | | | | | | | | | | | | | | | |
| Action 2.4.1 | conduct air launched attacks | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0.7 | 0.4 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Action 2.4.2 | conduct sea launched attacks | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 1 | 0 | 0.4 | 0 | 0 | 0 | 0 | 1 |
| Task 2.5 | clandestine military operations | | | | | | | | | | | | | | | | |
| Action 2.5.1 | recon | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Action 2.5.2 | PSYOPS and support to local government | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Task 2.6 | obtain and maintain air superiority | | | | | | | | | | | | | | | | |
| Action 2.6.1 | air to air superiority | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 1 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 2.6.2 | theater air defense | 0.1 | 0.2 | 0.2 | 0.5 | 0.2 | 0.5 | 0.6 | 1 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Task 2.7 | conduct sea warfare | | | | | | | | | | | | | | | | |
| Action 2.7.1 | conduct anti submarine operations | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0.7 | 0 | 0.6 | 0 | 0 | 0 | 1 | 5 |
| Action 2.7.2 | conduct anti surface operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.8 | 0 | 0.1 | 0 | 0 | 0.8 | 0 | 1 |
| Action 2.7.3 | conduct anti air operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.5 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 2.7.4 | conduct surface operations | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 2.7.5 | conduct attack air operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.5 | 0.2 | 0 | 0 | 0.3 | 0.2 | 0 | 0 | 1 |
| Action 2.7.6 | mine sweeping capabilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 |
| Task 2.8 | conduct of a major amphibious landing | | | | | | | | | | | | | | | | |
| Action 2.8.1 | conduct anti submarine operations | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 2.8.2 | conduct anti surface operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.8 | 0 | 0.1 | 0 | 0 | 0.8 | 0 | 1 |
| Action 2.8.3 | conduct anti air operations | 0 | 0 | 0 | 0.3 | 0 | 0 | 1 | 0.5 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Action 2.8.4 | conduct surface operations | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Action 2.8.5 | conduct attack air operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.5 | 0.2 | 0 | 0 | 0.3 | 0.2 | 0 | 0 | 0.5 |
| Action 2.8.6 | conduct close air support (CAS) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.3 |
| Action 2.8.7 | conduct ground combat against mounted units | 0.2 | 0.2 | 0.6 | 0.6 | 0.3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Action 2.8.8 | conduct ground combat against dismounted units | 0.3 | 0.3 | 0.7 | 0.7 | 0.5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |

*Table 4.4 continued*

| MTA | Description | Mission Effectiveness Values | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mission 3** | **Major Non UN Peace Enforcement, Serbia Versus Albania** | AA | LID | ACR | MEF | ASD | HD | CBG | FDA | SAG | SOF | SUB | HBW | RIEW | MW | ASF | Needed |
| Task 3.1 | enforcement of sanctions | | | | | | | | | | | | | | | | |
| Action 3.1.1 | enforce no fly zone | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 1 | 0.2 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.5 |
| Action 3.1.2 | enforce sea blockade | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0.5 |
| Task 3.2 | protection of humanitarian assistance | | | | | | | | | | | | | | | | |
| Action 3.2.1 | conduct ground combat against mounted units | 0.4 | 0.5 | 0.6 | 0.5 | 0.5 | 1 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Action 3.2.2 | conduct ground combat against dismounted units | 0.8 | 1 | 0.5 | 0.7 | 0.5 | 0.5 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Task 3.3 | forcible separation of belligerents | | | | | | | | | | | | | | | | |
| Action 3.3.1 | conduct ground combat against mounted units | 0.4 | 0.5 | 0.6 | 0.5 | 0.5 | 1 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Action 3.3.2 | conduct ground combat against dismounted units | 0.8 | 1 | 0.5 | 0.7 | 0.5 | 0.5 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Action 3.3.3 | conduct close air support (CAS) | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.5 | 0.6 | 0.2 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.2 |
| Task 3.4 | Minimum Troop Response | | | | | | | | | | | | | | | | |
| Action 3.4.1 | Place Army light division on the ground in 72 hours | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

***Table 4.4 continued***

| MTA | Description | Mission Effectiveness Value | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mission 1 | Show Of Force, Persian Gulf | AA | LID | ACR | MEF | ASD | HD | CBG | FDA | SAG | SOF | SUB | HBW | RIEW | MW | AS | Needed |
| Task 1.1 | conduct of a major sea training exercise | | | | | | | | | | | | | | | | |
| Action 1.1.1 | conduct anti submarine operations | 0 | 0 | 0 | 0.05 | 0 | 0 | 0.8 | 0 | 0.7 | 0 | 0.6 | 0 | 0 | 0 | 1 | 1 |
| Action 1.1.2 | conduct anti surface operations | 0 | 0 | 0 | 0.05 | 0 | 0 | 1 | 0 | 0.8 | 0 | 0.1 | 0 | 0 | 0.8 | 0 | 0.3 |
| Action 1.1.3 | conduct anti air operations | 0 | 0 | 0 | 0.2 | 0 | 0 | 1 | 0.5 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 |
| Action 1.1.4 | conduct surface operations | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 |
| Action 1.1.5 | conduct attack air operations | 0 | 0 | 0 | 0.2 | 0 | 0 | 1 | 0.5 | 0.2 | 0 | 0 | 0.3 | 0.2 | 0 | 0 | 0.3 |
| Task 1.2 | conduct major amphibious landing training exercise | | | | | | | | | | | | | | | | |
| Action 1.2.1 | conduct antisubmarine operations | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 1.2.2 | conduct anti surface operations | 0 | 0 | 0 | 0.6 | 0 | 0 | 1 | 0.5 | 0.5 | 0 | 0.5 | 0.2 | 0 | 0 | 0 | 0.3 |
| Action 1.2.3 | conduct anti air operations | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.5 | 0.7 | 0.8 | 0.4 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.3 |
| Action 1.2.4 | conduct surface operations | 0 | 0 | 0 | 1 | 0 | 0 | 0.6 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 |
| Action 1.2.5 | conduct attack air operations | 0.1 | 0.1 | 0.2 | 0.4 | 0.4 | 0.2 | 0.6 | 0.8 | 0.1 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0.3 |
| Action 1.2.6 | conduct close air support (CAS) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.3 |
| Action 1.2.7 | conduct ground combat against mounted units | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Action 1.2.8 | conduct ground combat against dismounted units | 0.2 | 1 | 0.4 | 0.4 | 0.6 | 0.6 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.4 |
| Task 1.3 | conduct of a dismounted infantry training exercise | | | | | | | | | | | | | | | | |
| Action 1.3.1 | conduct close air support (CAS) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.1 |
| Action 1.3.2 | conduct dismounted ground combat against mounted units | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| Action 1.3.3 | conduct dismounted ground combat against dismounted units | 0.2 | 1 | 0.4 | 0.4 | 0.6 | 0.6 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| Action 1.3.4 | maintain air superiority | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.4 | 1 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.1 |
| Action 1.3.5 | theater ballistic missile defense | 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 1 | 0.2 | 0.1 | 0.2 | 0 | 0.05 | 0.1 | 0.1 | 0 | 0 | 0.1 |
| Action 1.3.6 | electronic warfare ground | 0.4 | 0.2 | 0.2 | 0.4 | 0.4 | 1 | 0.2 | 0.2 | 0.2 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0.1 |
| Task 1.4 | conduct of a major air to air combat training exercise | | | | | | | | | | | | | | | | |
| Action 1.4.1 | maintain air superiority | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.4 | 1 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.1 |
| Action 1.4.2 | electronic warfare air | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.2 | 0 | 0.1 | 0 | 0 | 0 | 1 | 0 | 0 | 0.5 |
| Task 1.5 | minimum security of sea lanes | | | | | | | | | | | | | | | | |
| Action 1.5.1 | maintain CBG for security | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |

*Table 4.5 Scenario 2 - Missions, tasks, and actions and mission effectiveness values*

| MTA | Description | Mission Effectiveness Value | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mission 2 | Major Regional Conflict, China Versus Japan | AA | LID | ACR | MEF | ASD | HD | CBG | FDA | SAG | SOF | SUB | HBW | RIEW | MW | AS | Needed |
| Task 2.1 | conduct close air support (CAS) | | | | | | | | | | | | | | | | |
| Action 2.1.1 | maintain air superiority | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 1 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| Action 2.1.2 | electronic warfare | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0 | 0 | 0.1 | 1 | 0 | 0 | 2 |
| Action 2.1.3 | deep attack | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.2 | 0.2 | 0 | 0.2 | 0.7 | 0 | 0 | 0 | 1 |
| Task 2.2 | conduct of dismounted infantry warfare | | | | | | | | | | | | | | | | |
| Action 2.2.1 | conduct ground combat against mounted units | 0.2 | 1 | 0.4 | 0.4 | 0.4 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Action 2.2.2 | conduct ground combat against dismounted units | 0.4 | 1 | 0.6 | 0.7 | 0.5 | 0.4 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 2 |
| Task 2.3 | conduct of mounted warfare | | | | | | | | | | | | | | | | |
| Action 2.3.1 | conduct mounted combat against mounted units | 0.2 | 0.2 | 0.6 | 0.6 | 0.3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Action 2.3.2 | conduct mounted combat against dismounted units | 0.3 | 0.3 | 0.7 | 0.7 | 0.5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Task 2.4 | conduct strategic attacks against hardened targets | | | | | | | | | | | | | | | | |
| Action 2.4.1 | conduct air launched attacks | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0.7 | 0.4 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Action 2.4.2 | conduct sea launched attacks | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 1 | 0 | 0.4 | 0 | 0 | 0 | 0 | 1 |
| Task 2.5 | clandestine military operations | | | | | | | | | | | | | | | | |
| Action 2.5.1 | recon | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Action 2.5.2 | PSYOPS and support to local government | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.05 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Task 2.6 | obtain and maintain air superiority | | | | | | | | | | | | | | | | |
| Action 2.6.1 | air to air superiority | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 1 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 2.6.2 | theater air defense | 0.1 | 0.2 | 0.2 | 0.5 | 0.2 | 0.5 | 0.6 | 1 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Task 2.7 | conduct sea warfare | | | | | | | | | | | | | | | | |
| Action 2.7.1 | conduct antisubmarine operations | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0.7 | 0 | 0.6 | 0 | 0 | 0 | 1 | 20 |
| Action 2.7.2 | conduct anti surface operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.8 | 0 | 0.1 | 0 | 0 | 0.8 | 0 | 4 |
| Action 2.7.3 | conduct anti air operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.5 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Action 2.7.4 | conduct surface operations | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Action 2.7.5 | conduct attack air operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.5 | 0.2 | 0 | 0 | 0.3 | 0.2 | 0 | 0 | 3 |
| Action 2.7.6 | mine sweepingcapabilites | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 |
| Task 2.8 | conduct of a major amphibious landing | | | | | | | | | | | | | | | | |
| Action 2.8.1 | conduct antisubmarine operations | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| Action 2.8.2 | conduct anti surface operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.8 | 0 | 0.1 | 0 | 0 | 0.8 | 0 | 2 |
| Action 2.8.3 | conduct anti air operations | 0 | 0 | 0 | 0.3 | 0 | 0 | 1 | 0.5 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 2.8.4 | conduct surface operations | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Action 2.8.5 | conduct attack air operations | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.5 | 0.2 | 0 | 0 | 0.3 | 0.2 | 0 | 0 | 1 |
| Action 2.8.6 | conduct close air support (CAS) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 1 |
| Action 2.8.7 | conduct ground combat against mounted units | 0.2 | 0.2 | 0.6 | 0.6 | 0.3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Action 2.8.8 | conduct ground combat against dismounted units | 0.3 | 0.3 | 0.7 | 0.7 | 0.5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |

*Table 4.5 continued*

| MTA | Description | Mission Effectiveness Value | | | | | | | | | | | | | | | Total Needed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mission 3** | **Major Non UN Peace Enforcement, Hungary Versus Romania** | AA | LID | ACR | MEF | ASD | HD | CBG | FDA | SAG | SOF | SUB | HBW | RIEW | MW | AS | |
| Task 3.1 | enforcement of sanctions | | | | | | | | | | | | | | | | |
| Action 3.1.1 | enforce no fly zone | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 1 | 0.2 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.5 |
| Action 3.1.2 | enforce sea blockade | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0.5 |
| Task 3.2 | protection of humanitarian assistance | | | | | | | | | | | | | | | | |
| Action 3.2.1 | conduct ground combat against mounted units | 0.4 | 0.5 | 0.6 | 0.5 | 0.5 | 1 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Action 3.2.2 | conduct ground combat against dismounted units | 0.8 | 1 | 0.5 | 0.7 | 0.5 | 0.5 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Task 3.3 | forcible separation of belligerents | | | | | | | | | | | | | | | | |
| Action 3.3.1 | conduct ground combat against mounted units | 0.4 | 0.5 | 0.6 | 0.5 | 0.5 | 1 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Action 3.3.2 | conduct ground combat against dismounted units | 0.8 | 1 | 0.5 | 0.7 | 0.5 | 0.5 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.2 |
| Action 3.3.3 | conduct close air support (CAS) | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.5 | 0.6 | 0.2 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.2 |
| Task 3.4 | Minimum Troop Response | | | | | | | | | | | | | | | | |
| Action 3.4.1 | Place Army light division on the ground in 72 hours | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

*Table 4.5 continued*

| Number | Unit Name | Abbreviations | Costs ($1000k) | Maximum Number |
|---|---|---|---|---|
| 1 | Airborne Division | AA | 3250 | 1 |
| 2 | Light Infantry Division | LID | 2000 | 4 |
| 3 | Armored Cavalry Regiment | ACR | 3050 | 2 |
| 4 | Marine Expeditionary Force | MEF | 3050 | 6 |
| 5 | Air Assault Division | ASD | 3000 | 1 |
| 6 | Heavy Division | HD | 3000 | 4 |
| 7 | Carrier Battle Group | CBG | 3250 | 10 |
| 8 | Forward Deployable Aircraft | FDA | 2350 | 16 |
| 9 | Surface Action Group | SAG | 1500 | 5 |
| 10 | Special Operating Forces | SOF | 230 | 10 |
| 11 | Attack Submarine | SUB | 250 | 25 |
| 12 | Heavy Bomber Wing | HBW | 3000 | 2 |
| 13 | Recon, Intel, Elect War Wing | RIEW | 1800 | 2 |
| 14 | Mine Warfare | MW | 200 | 5 |
| 15 | Anti Sub Fixed And Rotary Wing | AS | 950 | 4 |

***Table 4.6 Unit names, abbreviations, costs, and maximum allowable numbers***

| Unit | Assigned To Scenario 1 | Assigned To Scenario 2 | Total Required |
|---|---|---|---|
| Airborne Division | 1 | 1 | 1 |
| Light Infantry Division | 1 | 0 | 1 |
| Armored Cavalry Regiment | 0 | 0 | 0 |
| Marine Expeditionary Force | 6 | 6 | 6 |
| Air Assault Division | 0 | 0 | 0 |
| Heavy Division | 3 | 2 | 3 |
| Carrier Battle Group | 2 | 2 | 2 |
| Forward Deployable Aircraft | 6 | 6 | 6 |
| Surface Action Group | 3 | 5 | 5 |
| Special Operating Forces | 4 | 3 | 4 |
| Submarines | 24 | 24 | 24 |
| Heavy Bomber Wing | 0 | 0 | 0 |
| Recon, Intel, Elect War Wing | 2 | 2 | 2 |
| Mine Warfare | 4 | 4 | 4 |
| Anti Sub Aircraft | 0 | 3 | 3 |

***Table 4.7 Model results from demonstration study***

## 5.0 Summary and Conclusions

A methodology has been presented that provides the framework for performing meaningful force structuring tradeoff analysis for OOTW and the traditional warfighting missions. Though centered around a mathematical programming approach, the methodology is unique in that

- the force can be designed around multiple scenarios,
- the methodology contains a hierarchical approach to defining the contributions of the units of interest to accomplishing a specified for both warfighting and OOTW types missions.

A prototype was developed using the GAMS language and a proof-of-principal demonstration study was conducted using nominal data values. However, to extend the model to more realistic situations, additional research is needed to quantify

- the contribution of each unit type to each action needed in the scenarios,
- the requirements of each action for each task,
- the cost of each unit,
- the degradation of units as a function of time and mission assignment, and
- the costs and impacts of reassigning units within a scenario after mission completion.

The next logical task is a true proof-of-principal study using hundreds of units and a large set of missions. This task will determine if the problem is solvable and the input data requirements are manageable.

In summary, the methodology has potential to be used to perform force structuring tradeoff analysis from a joint perspective. If the model can perform this function, the obvious extension is to analyze force modernization issues across the services.

## 6.0 References

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# Appendix A - Acronyms and Abbreviations

| Abbreviation | Description |
|---|---|
| ASD | Air Assault Division |
| ACR | Armored Cavalry Regiment |
| AA | Airborne Division |
| SUB | Attack Submarine |
| AS | Anti Sub Fixed and Rotary Wing Aircraft |
| CAS | Close Air Support |
| CBG | Carrier Battle Group |
| CINC | Commander In Chief |
| CONUS | Continental United States |
| DA | Department of the Army |
| DAG | Directed Acyclic Graph |
| DOD | Department of Defense |
| DPG | Defense Planning Guidance |
| DSE | Department of Systems Engineering |
| FEA | Front End Analysis |
| FDA | Forward Deployable Aircraft |
| FY | Fiscal Year |
| GAMS | General Algebraic Modeling System |
| GMU | George Mason University |
| HA | Humanitarian Assistance |
| HBW | Heavy Bomber Wing |
| HD | Heavy Division |
| IP | Integer Program |
| LID | Light Infantry Division |
| MAA | Mission Area Analysis |
| MEF | Marine Expeditionary Force |
| MILP | Mixed Integer Linear Program |
| MILPO | Military Political |
| MOE | Measure of Effectiveness |
| MOIP | Multi Objective Integer Program |
| MP | Mathematical Programming |
| MRC | Major Regional Conflict |
| MW | Mine Warfare |
| ODPA&E | Office of the Secretary of Defense, Program Analysis and Evaluation |
| OOTW | Operations Other Than War |
| PE | Peace Enforcement |
| PHD | Peacekeeping, Humanitarian, and Disaster |

| Abbreviation | Description |
|---|---|
| PK | Peacekeeping |
| POM | Program Objective Memorandum |
| PPBS | Planning-Programming-Budgeting System |
| R&D | Research and Development |
| RAMCO | Resource Allocation Model for Contingency Operations |
| RHS | Right Hand Side |
| RIEW | Recon, Intel, Elect War Wing |
| SAC | Simulation Analysis Center |
| SAG | Surface Action Group |
| SOF | Special Operation Forces |
| UN | United Nations |
| USACE | U.S. Army Corps of Engineers |
| U.S. | United States |
| USMA | U.S. Military Academy |
| V&V | Verification and Validation |
| WEI/WUV | Weapon Effectiveness Index/Weighted Unit Value |

# Appendix B - GAMS Implementation of Methodology

GAMS model for force structuring project

Sets
Scenarios
Missions
Tasks
Actions
Units
Subsets
Missions in Scenario s
Tasks in Mission m
Actions in Task t

Really, the missions and scenarios are irrelevant. What is key is a list of tasks and set pointers on which tasks go together into the missions. If no missions share tasks and not scenarios share missions, then all we need is a list of tasks and the su

Tables and vectors
Amount of action A that can be done by unit U (constraint coefficient)
Amount of action A that is necessary for task T in mission M in scenario S (rhs coefficient)
Cost of unit U (obj or constraint coefficient)
Number of unit U available (rhs coefficient)
importance of scenario s (obj coefficient)
functions
Constraint forms linking actions included to task and hence mission success.
Objective
constraints on things like availability
constraints on issues such as units that go together (if you use u for a mission, then you also must use u')
constraints on availability.

```
SET    S            set of scenarios
               / SEN1*SEN2 / ;
SET    M              missions for the scenarios
               / MSOFCHINA, MMRCIRAQ, MMPESERBIA, MSOF
                MMRCCHINA  /  ;

*         MSOFCHINA is major show of force in china
*         MMRCIRAQ is major regional conflict in Iraq
```

```
*         MMPESERBIA is major non UN peace enforcement, Servia vs
                                        Albania
*         MSOF is major show of force sea lanes in mid east
*         MRCCHINA is a major regional conflict in china

SET    T        tasks that go into missions this must be all tasks
          / TMST, TMALE, TDIT, TAAC, TCAS, TDIW, TMW, TSAHT, TCMO
            TOMAS, TSW, TMAL, TES, PHA, FSB, MSSL / ;
*          no repeats that can go to missions
*          if an identical task is required in 2 missions, then fine.
*          If anything changes, then this must be


*            TMST is major sea training exercise
*            TMALE is major amphibious landing training exercise
*            TDIT is dismounted infantry training exercise
*            TAAC is major air to air combat exercise
*            TCAS is close air support
*            TDIW is dismounted infantry warfare
*            TMW is mounted warfare
*            TSAHT is strategic attacks against hardened targets
*            TCMO is clandestine military operations
*            TOMAS is obtain and maintain air superiority
*            TSW is sea warfare
*            TMAL is major amphibious landing
*            TES is enforcement of sanctions
*            PHA is protection of humanitarian assistance
*            FSB is forcible separation of belligerents
*            MSSL is minimum security of sea lanes

SET    A        actions that are needed for tasks
                /ACT1*ACT57/ ;

*         ACTION 55 WAS ADDED LATE (CORRESPONDS TO ACTION 2.2.3)
*         Action 56 was added late  Maintain CBG for fwd presence
*         Action 57 was added late (in conduct sea war to get MW)
*         REST OF ACTIONS FOLLOW ORDER ON THE SHEET

SET    U        units that can do actions to perform tasks
         /  AA, LID, ACR, MEF, ASD, HD, CBG, FDA,
          SAG, SOF, SUB, HBW, RIEW, MW, AS/ ;
       AA        airborne division, active
       LID       light infantry division, active
```

```
            ACR     armored cavalry regiment, active
            MEF     marine expeditionary force, active
            ASD     air assault division, active
            HD      heavy division, active
            CBG     carrier battle group
            FDA     forward deployable aircraft, active
            SAG     surface action group, active
            SOF     special operating forces
            SUB     attack submarine, active
            HBW     heavy bomber wing, active
            RIEW    recon, intel, elect war wing, active
            MW      mine warfare, active
            AS      anti-sub fixed and rotary wing

SET     SM(S, M)     set of missions in each scenario
            /SEN1.MSOFCHINA
             SEN1.MMRCIRAQ
             SEN1.MMPESERBIA
             SEN2.MSOF
             SEN2.MMRCCHINA
             SEN2.MMPESERBIA    / ;

SET     MT(M, T)     set of tasks for each mission
        / MSOFCHINA.TMST, MSOFCHINA.TMALE, MSOFCHINA.TDIT,
                              MSOFCHINA.TAAC
          MMRCIRAQ.TCAS, MMRCIRAQ.TDIW, MMRCIRAQ.TMW,
MMRCIRAQ.TSAHT
          MMRCIRAQ.TCMO, MMRCIRAQ.TOMAS, MMRCIRAQ.TSW,
MMRCIRAQ.TMAL
          MMPESERBIA.TES, MMPESERBIA.PHA, MMPESERBIA.FSB
          MSOF.TMST, MSOF.TMALE, MSOF.TDIT, MSOF.TAAC, MSOF.MSSL
          MMRCCHINA.TCAS, MMRCCHINA.TDIW, MMRCCHINA.TMW,
                              MMRCCHINA.TSAHT
          MMRCCHINA.TCMO, MMRCCHINA.TOMAS, MMRCCHINA.TSW,
                              MMRCCHINA.TMAL
        / ;


SET     AT(T, A)     set of actions in each task
        /   TMST.ACT1, TMST.ACT2, TMST.ACT3, TMST.ACT4, TMST.ACT5
            TMALE.ACT6, TMALE.ACT7, TMALE.ACT8, TMALE.ACT9,
                              TMALE.ACT10
                  TMALE.ACT11, TMALE.ACT12, TMALE.ACT13
```

```
             TDIT.ACT14, TDIT.ACT15, TDIT.ACT16, TDIT.ACT17,
                                   TDIT.ACT18
             TAAC.ACT19, TAAC.ACT20
             TCAS.ACT21, TCAS.ACT22, TCAS.ACT23
             TDIW.ACT24, TDIW.ACT25
             TMW.ACT26, TMW.ACT27, TMW.ACT55
             TSAHT.ACT28, TSAHT.ACT29
             TCMO.ACT30, TCMO.ACT31
             TOMAS.ACT32, TOMAS.ACT33
             TSW.ACT34, TSW.ACT35, TSW.ACT36, TSW.ACT37, TSW.ACT38,
                 TSW.ACT57
             TMAL.ACT39, TMAL.ACT40, TMAL.ACT41, TMAL.ACT42,
             TMAL.ACT43,
                 TMAL.ACT44, TMAL.ACT45, TMAL.ACT46,
                                   TMAL.ACT47
             TES.ACT48, TES.ACT49
             PHA.ACT50, PHA.ACT51
             FSB.ACT52, FSB.ACT53, FSB.ACT54
             MSSL.ACT56
             / ;


 TABLE  UA(A,U)         amount each unit U can do of each
                                   action A
INCLUDE C:\FORCESTR\DEMO.PRN
              AA  LID  ACR  MEF  ASD  HD  CBG  FDA  SAG
                   SOF  SUB  HBW  RIEW  MW   AS
 Act1          0   0    0   0.05  0    0   0.8   0   0.7
                    0   0.6   0     0    0    1
 Act2          0   0    0   0.05  0    0   1     0   0.8
                    0   0.1   0     0   0.8   0
 Act3          0   0    0   0.2   0    0   1    0.5  0.4
                    0   0     0     0    0    0
 Act4          0   0    0   0.1   0    0   0.5   0   1
                    0   0     0     0    0    0
 Act5          0   0    0   0.2   0    0   1    0.5  0.2
                    0   0    0.3   0.2   0    0
 Act6          0   0    0   0.5   0    0   0     0   1
                    0   0     0     0    0    0
 Act7          0   0    0   0.6   0    0   1    0.5  0.5
                    0   0.5  0.2    0    0    0
 Act8         0.2 0.3  0.4  0.4  0.4  0.5  0.7  0.8  0.4
                    0   0    0.1    0    0    0
```

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 152 | Act9 | 0 | 0 | 0 | 1 | 0 | 0 | 0.6 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 153 | Act10 | 0.1 | 0.1 | 0.2 | 0.4 | 0.4 | 0.2 | 0.6 | 0.8 | 0.1 | 0 | 0 | 0.2 | 0 | 0 | 0 |
| 154 | Act11 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 |
| 155 | Act12 | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| 156 | Act13 | 0.2 | 1 | 0.4 | 0.4 | 0.6 | 0.6 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| 157 | Act14 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 |
| 158 | Act15 | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| 159 | Act16 | 0.2 | 1 | 0.4 | 0.4 | 0.6 | 0.6 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| 160 | Act17 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.4 | 1 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 |
| 161 | Act18 | 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 1 | 0.2 | 0.1 | 0.2 | 0 | 0.05 | 0.1 | 0.1 | 0 | 0 |
| 162 | Act19 | 0.4 | 0.2 | 0.2 | 0.4 | 0.4 | 1 | 0.2 | 0.2 | 0.2 | 0.1 | 0 | 0 | 0.1 | 0 | 0 |
| 163 | Act20 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.4 | 1 | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 |
| 164 | Act21 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.2 | 0.0 | 0.1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 165 | Act22 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 1 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 166 | Act23 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0 | 0 | 0.1 | 1 | 0 | 0 |
| 167 | Act24 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.2 | 0.2 | 0 | 0.2 | 0.7 | 0 | 0 | 0 |
| 168 | Act25 | 0.2 | 1 | 0.4 | 0.4 | 0.4 | 1 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| 169 | Act26 | 0.4 | 1 | 0.6 | 0.5 | 0.5 | 0.4 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 |
| 170 | Act27 | 0.2 | 0.2 | 0.6 | 0.5 | 0.3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 171 | Act28 | 0.3 | 0.3 | 0.7 | 1 | 0.5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 172 | Act29 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0.7 | 0.4 | 0 | 0 | 1 | 0 | 0 | 0 |
| 173 | Act30 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 1 | | | | | | |

0 0.4 0 0 0 0

174 Act31 0.1 0.1 0.1 0.1 0.1 0.05 0 0 0
1 0 0 0 0 0

175 Act32 0.1 0.1 0.1 0.1 0.1 0.05 0 0 0
1 0 0 0 0 0

176 Act33 0 0 0 0 0 0 0.5 1 0.2
0 0 0 0 0 0

177 Act34 0.1 0.2 0.2 0.5 0.2 0.5 0.6 1 0.2
0 0 0 0 0 0

178 Act35 0 0 0 0 0 0 0.8 0 0.7
0 0.6 0 0 0 1

179 Act36 0 0 0 0 0 0 1 0 0.8
0 0.1 0 0 0.8 0

180 Act37 0 0 0 0 0 0 1 0.5 0.4
0 0 0 0 0 0

181 Act38 0 0 0 0 0 0 0.5 0 1
0 0 0 0 0 0

182 Act39 0 0 0 0 0 0 1 0.5 0.2
0 0 0.3 0.2 0 0

183 Act40 0 0 0 1 0 0 0 0 1
0 0 0 0 0 0

184 Act41 0 0 0 0 0 0 1 0 0.8
0 0.1 0 0 0.8 0

185 Act42 0 0 0 0.3 0 0 1 0.5 0.4
0 0 0 0 0 0

186 Act43 0 0 0 0.1 0 0 0.5 0 1
0 0 0 0 0 0

187 Act44 0 0 0 0 0 0 1 0.5 0.2
0 0 0.3 0.2 0 0

188 Act45 0.3 0.3 0.3 0.3 0.3 0.4 0.3 0.4 0.1
0 0 0.1 0 0 0

189 Act46 0.2 0.2 0.6 0.6 0.3 0.3 0 0 0
0 0 0 0 0 0

190 Act47 0.3 0.3 0.7 0.7 0.3 0.3 0 0 0
0 0 0 0 0 0

191 Act48 0 0 0 0 0 0 0.6 1 0.2
0 0 0 0.1 0 0

192 Act49 0 0 0 0 0 0 1 0 1
0 0 0 0 0.4 0

193 Act50 0.4 0.5 0.6 0.5 0.5 1 0 0 0
0.05 0 0 0 0 0

194 Act51 0.8 1 0.5 0.7 0.5 0.5 0 0 0
0.05 0 0 0 0 0

```
Act52        0.4  0.5  0.6  0.5  0.5   1    0    0    0
                       0.05  0    0    0    0    0
Act53        0.8   1   0.5  0.7  0.5  0.5   0    0    0
                       0.05  0    0    0    0    0
Act54        0.1  0.1  0.1  0.2  0.3  0.3  0.5  0.6  0.2
                        0    0    0   0.1   0    0
Act55         1    0    0    0    0    0    0    0    0
                        0    0    0    0    0    0
Act56         0    0    0    0    0    0    1    0    0
                        0    0    0    0    0    0
Act57         0    0    0    0    0    0    0    0    0
                        0    0    0    0    1    0

TABLE   REQ(T, A, M)      amount of action A needed in task T mission m
                MSOFCHINA  MMRCIRAQ  MMPESERBIA   MSOF   MMRCCHINA
     TMST.ACT1        1                  1
     TMST.ACT2        0.3                0.3
     TMST.ACT3        0.3                0.3
     TMST.ACT4        0.3                0.3
     TMST.ACT5        0.3                0.3
     TMALE.ACT6         1                  1
     TMALE.ACT7       0.3                0.3
     TMALE.ACT8       0.3                0.3
     TMALE.ACT9       0.3                0.3
     TMALE.ACT10       0.3                0.3
     TMALE.ACT11       0.3                0.3
     TMALE.ACT12       0.2                0.2
     TMALE.ACT13       0.4                0.4
     TDIT.ACT14       0.1                0.1
     TDIT.ACT15       0.1                0.1
     TDIT.ACT16       0.1                0.1
     TDIT.ACT17       0.1                0.1
     TDIT.ACT18       0.1                0.1
     TDIT.ACT19       0.1                0.1
     TAAC.ACT20        0.1                0.1
     TAAC.ACT21        0.1                0.5
     TCAS.ACT22               6                  6
     TCAS.ACT23               2                  2
     TCAS.ACT24               1                  1
     TDIW.ACT25               6                  2
     TDIW.ACT26               6                  2
     TMW.ACT27                5                  3
     TMW.ACT28                5                  2
```

```
        TSAHT.ACT29        1             1
        TSAHT.ACT30        1             1
        TCMO.ACT31         3             3
        TCMO.ACT32         3             3
        TOMAS.ACT33        1             1
        TOMAS.ACT34        0.5           0.5
        TSW.ACT35         5             20
        TSW.ACT36         1             4
        TSW.ACT37         1             4
        TSW.ACT38         1             2
        TSW.ACT39         1             3
        TMAL.ACT40         1             10
        TMAL.ACT41         1             2
        TMAL.ACT42        0.5             1
        TMAL.ACT43        0.5             1
        TMAL.ACT44        0.5             1
        TMAL.ACT45        0.3             1
        TMAL.ACT46        0.5             2
        TMAL.ACT47        0.5             2
        TES.ACT48            0.5
        TES.ACT49            0.5
        PHA.ACT50             0.2
        PHA.ACT51             0.2
        FSB.ACT52            0.2
        FSB.ACT53            0.2
        FSB.ACT54            0.2
        TMW.ACT55         1              1
        MSSL.ACT56                 1
        TSW.ACT57         4             4
                   ;
  PARAMETER   NUM(U)          number of units of each type
                              available
            /   AA     1
                LID    4
                ACR    2
                MEF    6
                ASD    1
                HD     4
                CBG    10
                FDA    16
                SAG    5
                SOF    10
                SUB    25
```

```
              HBW     2
              RIEW    2
              MW      5
              AS      4 / ;
PARAMETER  IMP(S)              importance of scenario s
*                    not used right now

PARAMETER  COST(U)             cost of each unit U
        /    AA      3250
             LID     2000
             ACR     2050
             MEF     3050
             ASD     3000
             HD      3000
             CBG     3250
             FDA     2350
             SAG     1500
             SOF     230
             SUB     250
             HBW     3000
             RIEW    1800
             MW      200
             AS      950                  / ;

SCALAR     DAYS     days per year    /250/ ;

VARIABLES
   X(U, S, M)  number of units U assigned to each mission M in
                                  scenario S
   NU(U)      number of each unit picked
        at this point, we assume that if a unit is assigned to
         a mission, it can be used for any task on the mission.
        at some time, we may assign units to tasks.  Now, we
           actually have an extra level in that we could just
        set actions to missions (instead we go through tasks).
           This is easily seen in the sum of task constraints.
        We assume that all tasks for a mission must be done for
                              mission success.

TOTCOST               variable for the objective  ;
INTEGER VARIABLES   NU, X ;
FREE VARIABLES  TOTCOST  ;
```

```
314 EQUATIONS
315   OBJ        objective of min cost
316   ASS(A, S, M)  sum of actions of units assigned to mission must be
317 *            sufficient for the tasks in that mission for each
                                       scenario
318
319   CAP(S, U)    don't go over the allowable number of units to assign
320 *             that you payed for
321   BCAP(U)      don't pay for more than you can take  ;
322
323   OBJ..     TOTCOST =E= SUM(U, NU(U) * COST(U)) ;
324
325   ASS(A, S, M)$SM(S, M).. SUM(U, X(U, S, M) * UA(A, U))
326                  =G= SUM(T$MT(M, T), REQ(T, A, M))  ;
327
328   CAP(S, U).. SUM(M$SM(S, M), X(U, S, M) ) =L= NU(U)  ;
329
330   BCAP(U)..  NU(U) =L= NUM(U) ;
331
332 MODEL   TEST     test case to see if this works   /ALL/ ;
333
334 OPTION ITERLIM = 3500 ;
335
336 SOLVE   TEST   USING  MIP  MINIMIZING  TOTCOST ;
337
338
```

NOTES for Jeff
nothing yet for the scenarios. need to work this into the objective in maximizing weighted success probability.
success probability is a function of mission success (multiply together). Mission success is a function of units assigned to missions. Need to replace task requirements with levels to map to probabilities. Assume that if you assign enough to mission

```
SYMBOL    TYPE   REFERENCES

A       SET   DECLARED      70 DEFINED     71    REF     118
             141     202     316     325     326
           CONTROL    325
ASS      EQU   DECLARED     316  DEFINED     325 IMPL-ASN      336
             REF     332
AT       SET   DECLARED     118  DEFINED     119
```

```
BCAP     EQU  DECLARED    321 DEFINED    330 IMPL-ASN    336
            REF   332
CAP      EQU  DECLARED    319 DEFINED    328 IMPL-ASN    336
            REF   332
COST     PARAM DECLARED   281 DEFINED    282    REF    323
DAYS     PARAM DECLARED   298 DEFINED    298
IMP      PARAM DECLARED   278
M        SET  DECLARED    35 DEFINED     36    REF     99
            107    202    301    316   2*325  2*326
           2*328 CONTROL    325    328
MT       SET  DECLARED    107 DEFINED    108    REF    326
NU       VAR  DECLARED    302 IMPL-ASN    336    REF    311
            323    328    330
NUM      PARAM DECLARED   262 DEFINED    263    REF    330
OBJ      EQU  DECLARED    315 DEFINED    323 IMPL-ASN    336
            REF   332
REQ      PARAM DECLARED   202 DEFINED    202    REF    326
S        SET  DECLARED    33 DEFINED     34    REF     99
            278    301    316    319   2*325  2*328
           CONTROL    325    328
SM       SET  DECLARED    99 DEFINED     100    REF    325
            328
T        SET  DECLARED    45 DEFINED     46    REF    107
            118    202   2*326 CONTROL    326
TEST     MODEL DECLARED   332 DEFINED    332 IMPL-ASN    336
            REF   336
TOTCOST  VAR  DECLARED    310 IMPL-ASN    336    REF    312
            323    336
U        SET  DECLARED    78 DEFINED     79    REF    141
            262    281    301    302    319    321
           2*323  2*325  2*328  2*330 CONTROL    323
            325    328    330
UA       PARAM DECLARED   141 DEFINED    141    REF    325
X        VAR  DECLARED    301 IMPL-ASN    336    REF    311
            325    328
```

SETS

| | |
|---|---|
| A | actions that are needed for tasks |
| AT | set of actions in each task |
| M | missions for the scenarios |
| MT | set of tasks for each mission |

S set of scenarios
SM set of missions in each scenario

SETS

T tasks that go into missions this must be all tasks
U units that can do actions to perform tasks

PARAMETERS

COST cost of each unit U
DAYS days per year
IMP importance of scenario s
NUM number of units of each type available
REQ amount of action A needed in task T mission m
UA amount each unit U can do of each action A

VARIABLES

NU number of each unit picked
TOTCOST variable for the objective
X number of units U assigned to each mission M in scenario S

EQUATIONS

ASS sum of actions of units assigned to mission must be
BCAP don't pay for more than you can take
CAP don't go over the allowable number of units to assign
OBJ objective of min cost

MODELS

TEST test case to see if this works

Include File Summary

SEQ GLOBAL TYPE PARENT LOCAL FILENAME

1 1 INPUT 0 0 L:\FY96\OSD\MODELS\MODEL.GMS
2 142 INCLUDE 1 142 .C:\FORCESTR\DEMO.PRN

COMPILATION TIME = 0.990 SECONDS VERID MW2-25-085

Equation Listing SOLVE TEST USING MIP FROM LINE 336

---- OBJ =E= objective of min cost

OBJ.. - 3250*NU(AA) - 2000*NU(LID) - 2050*NU(ACR) - 3050*NU(MEF)

- 3000*NU(ASD) - 3000*NU(HD) - 3250*NU(CBG) - 2350*NU(FDA)

- 1500*NU(SAG) - 230*NU(SOF) - 250*NU(SUB) - 3000*NU(HBW)

- 1800*NU(RIEW) - 200*NU(MW) - 950*NU(AS) + TOTCOST =E= 0 ; (LHS = 0)

---- ASS =G= sum of actions of units assigned to mission must be

ASS(ACT1,SEN1,MSOFCHINA).. 0.05*X(MEF,SEN1,MSOFCHINA)

+ 0.8*X(CBG,SEN1,MSOFCHINA) + 0.7*X(SAG,SEN1,MSOFCHINA)

+ 0.6*X(SUB,SEN1,MSOFCHINA) + X(AS,SEN1,MSOFCHINA) =G= 1 ;

(LHS = 0 ***)

ASS(ACT1,SEN1,MMRCIRAQ).. 0.05*X(MEF,SEN1,MMRCIRAQ)

+ 0.8*X(CBG,SEN1,MMRCIRAQ) + 0.7*X(SAG,SEN1,MMRCIRAQ)

+ 0.6*X(SUB,SEN1,MMRCIRAQ) + X(AS,SEN1,MMRCIRAQ) =G= 0 ; (LHS = 0)

ASS(ACT1,SEN1,MMPESERBIA).. 0.05*X(MEF,SEN1,MMPESERBIA)

+ 0.8*X(CBG,SEN1,MMPESERBIA) + 0.7*X(SAG,SEN1,MMPESERBIA)

+ 0.6*X(SUB,SEN1,MMPESERBIA) + X(AS,SEN1,MMPESERBIA) =G= 0 ; (LHS = 0)

REMAINING 339 ENTRIES SKIPPED

---- CAP =L= don't go over the allowable number of units to assign

CAP(SEN1,AA).. X(AA,SEN1,MSOFCHINA) + X(AA,SEN1,MMRCIRAQ)

+ X(AA,SEN1,MMPESERBIA) - NU(AA) =L= 0 ; (LHS = 0)

CAP(SEN1,LID).. X(LID,SEN1,MSOFCHINA) + X(LID,SEN1,MMRCIRAQ)

+ X(LID,SEN1,MMPESERBIA) - NU(LID) =L= 0 ; (LHS = 0)

CAP =L= don't go over the allowable number of units to assign

CAP(SEN1,ACR).. X(ACR,SEN1,MSOFCHINA) + X(ACR,SEN1,MMRCIRAQ)

+ X(ACR,SEN1,MMPESERBIA) - NU(ACR) =L= 0 ; (LHS = 0)

REMAINING 27 ENTRIES SKIPPED

---- BCAP =L= don't pay for more than you can take

BCAP(AA).. NU(AA) =L= 1 ; (LHS = 0)

BCAP(LID).. NU(LID) =L= 4 ; (LHS = 0)

BCAP(ACR).. NU(ACR) =L= 2 ; (LHS = 0)

REMAINING 12 ENTRIES SKIPPED

---- X number of units U assigned to each mission M in scenario S

```
---- NU        number of each unit picked

NU(AA)
          (.LO, .L, .UP = 0, 0, 100)
  -3250     OBJ
     -1    CAP(SEN1,AA)

NU        number of each unit picked

     -1    CAP(SEN2,AA)
      1    BCAP(AA)

NU(LID)
          (.LO, .L, .UP = 0, 0, 100)
  -2000     OBJ
     -1    CAP(SEN1,LID)
     -1    CAP(SEN2,LID)
      1    BCAP(LID)

NU(ACR)
          (.LO, .L, .UP = 0, 0, 100)
  -2050     OBJ
     -1    CAP(SEN1,ACR)
     -1    CAP(SEN2,ACR)
      1    BCAP(ACR)

REMAINING 12 ENTRIES SKIPPED


---- TOTCOST    variable for the objective


TOTCOST
          (.LO, .L, .UP = -INF, 0, +INF)
      1    OBJ

MODEL STATISTICS

BLOCKS OF EQUATIONS      4    SINGLE EQUATIONS     388
BLOCKS OF VARIABLES      3    SINGLE VARIABLES     106
NON ZERO ELEMENTS     2053    DISCRETE VARIABLES   105
```

GENERATION TIME = 1.050 SECONDS

EXECUTION TIME = 1.050 SECONDS VERID MW2-25-085

SOLVE SUMMARY

MODEL TEST OBJECTIVE TOTCOST
TYPE MIP DIRECTION MINIMIZE
SOLVER OSL FROM LINE 336

**** SOLVER STATUS 1 NORMAL COMPLETION
**** MODEL STATUS 8 INTEGER SOLUTION
**** OBJECTIVE VALUE 74820.0000

RESOURCE USAGE, LIMIT 11.590 1000.000
ITERATION COUNT, LIMIT 152 3500

Work space allocated -- 0.66 Mb

Relaxed optimum objective value: 66334.125
Bound on best integer solution: 69309.839
Objective value of this solution: 74820.000

Relative gap: .07950 Absolute gap: 5510.1606
Optcr : .10000 Optca: 0.0

The solution satisfies the termination tolerances

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| ---- EQU OBJ | . | . | . | 1.000 |

OBJ objective of min cost

---- EQU ASS sum of actions of units assigned to mission must be

EQU ASS sum of actions of units assigned to mission must be

LOWER LEVEL UPPER MARGINAL

| | | | | |
|---|---|---|---|---|
| ACT20.SEN1.MMRCIRAQ | . | 6.900 | +INF | . |
| ACT20.SEN1.MMPESERBIA | . | 1.000 | +INF | . |
| ACT20.SEN2.MMPESERBIA | . | 0.400 | +INF | . |
| ACT20.SEN2.MSOF | 0.100 | 0.500 | +INF | . |
| ACT20.SEN2.MMRCCHINA | . | 7.600 | +INF | . |
| ACT21.SEN1.MSOFCHINA | 0.100 | 0.300 | +INF | . |
| ACT21.SEN1.MMRCIRAQ | . | 2.500 | +INF | . |
| ACT21.SEN1.MMPESERBIA | . | 0.500 | +INF | . |
| ACT21.SEN2.MMPESERBIA | . | 0.200 | +INF | . |
| ACT21.SEN2.MSOF | 0.500 | 1.300 | +INF | . |
| ACT21.SEN2.MMRCCHINA | . | 2.000 | +INF | . |
| ACT22.SEN1.MSOFCHINA | . | 0.600 | +INF | . |
| ACT22.SEN1.MMRCIRAQ | 6.000 | 6.300 | +INF | . |
| ACT22.SEN1.MMPESERBIA | . | 1.000 | +INF | . |
| ACT22.SEN2.MMPESERBIA | . | 0.500 | +INF | . |
| ACT22.SEN2.MSOF | . | 0.800 | +INF | . |
| ACT22.SEN2.MMRCCHINA | 6.000 | 7.200 | +INF | . |
| ACT23.SEN1.MSOFCHINA | . | 0.200 | +INF | . |
| ACT23.SEN1.MMRCIRAQ | 2.000 | 2.700 | +INF | . |
| ACT23.SEN1.MMPESERBIA | . | 0.200 | +INF | . |
| ACT23.SEN2.MMPESERBIA | . | 0.100 | +INF | . |
| ACT23.SEN2.MSOF | . | 1.200 | +INF | . |
| ACT23.SEN2.MMRCCHINA | 2.000 | 2.000 | +INF | 1800.000 |
| ACT24.SEN1.MSOFCHINA | . | 0.400 | +INF | . |
| ACT24.SEN1.MMRCIRAQ | 1.000 | 6.200 | +INF | . |
| ACT24.SEN1.MMPESERBIA | . | 0.400 | +INF | . |
| ACT24.SEN2.MMPESERBIA | . | 0.200 | +INF | . |
| ACT24.SEN2.MSOF | . | 0.400 | +INF | . |
| ACT24.SEN2.MMRCCHINA | 1.000 | 6.800 | +INF | . |
| ACT25.SEN1.MSOFCHINA | . | 0.400 | +INF | . |
| ACT25.SEN1.MMRCIRAQ | 6.000 | 6.200 | +INF | . |
| ACT25.SEN1.MMPESERBIA | . | 0.400 | +INF | . |
| ACT25.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT25.SEN2.MSOF | . | 1.000 | +INF | . |
| ACT25.SEN2.MMRCCHINA | 2.000 | 2.900 | +INF | . |
| ACT26.SEN1.MSOFCHINA | . | 0.500 | +INF | . |
| ACT26.SEN1.MMRCIRAQ | 6.000 | 6.200 | +INF | . |
| ACT26.SEN1.MMPESERBIA | . | 0.500 | +INF | . |
| ACT26.SEN2.MMPESERBIA | . | 0.400 | +INF | . |
| ACT26.SEN2.MSOF | . | 0.400 | +INF | . |
| ACT26.SEN2.MMRCCHINA | 2.000 | 4.600 | +INF | . |
| ACT27.SEN1.MSOFCHINA | . | 0.500 | +INF | . |

| | | | | |
|---|---|---|---|---|
| ACT27.SEN1.MMRCIRAQ | 5.000 | 5.400 | +INF | . |
| ACT27.SEN1.MMPESERBIA | . | 0.500 | +INF | . |
| ACT27.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT27.SEN2.MSOF | . | 1.000 | +INF | . |
| ACT27.SEN2.MMRCCHINA | 3.000 | 3.200 | +INF | . |
| ACT28.SEN1.MSOFCHINA | . | 1.000 | +INF | . |
| ACT28.SEN1.MMRCIRAQ | 5.000 | 7.600 | +INF | . |

EQU ASS sum of actions of units assigned to mission must be

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| ACT28.SEN1.MMPESERBIA | . | 1.000 | +INF | . |
| ACT28.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT28.SEN2.MSOF | . | 1.000 | +INF | . |
| ACT28.SEN2.MMRCCHINA | 2.000 | 6.300 | +INF | . |
| ACT29.SEN1.MSOFCHINA | . | 0.800 | +INF | . |
| ACT29.SEN1.MMRCIRAQ | 1.000 | 4.600 | +INF | . |
| ACT29.SEN1.MMPESERBIA | . | 1.400 | +INF | . |
| ACT29.SEN2.MMPESERBIA | . | 0.700 | +INF | . |
| ACT29.SEN2.MSOF | . | 1.100 | +INF | . |
| ACT29.SEN2.MMRCCHINA | 1.000 | 5.800 | +INF | . |
| ACT30.SEN1.MSOFCHINA | . | 2.000 | +INF | . |
| ACT30.SEN1.MMRCIRAQ | 1.000 | 10.600 | +INF | . |
| ACT30.SEN1.MMPESERBIA | . | 0.800 | +INF | . |
| ACT30.SEN2.MMPESERBIA | . | 0.400 | +INF | . |
| ACT30.SEN2.MSOF | . | 1.400 | +INF | . |
| ACT30.SEN2.MMRCCHINA | 1.000 | 13.600 | +INF | . |
| ACT31.SEN1.MSOFCHINA | . | 0.100 | +INF | . |
| ACT31.SEN1.MMRCIRAQ | 3.000 | 4.750 | +INF | . |
| ACT31.SEN1.MMPESERBIA | . | 0.100 | +INF | . |
| ACT31.SEN2.MMPESERBIA | . | 0.050 | +INF | . |
| ACT31.SEN2.MSOF | . | 0.050 | +INF | . |
| ACT31.SEN2.MMRCCHINA | 3.000 | 3.700 | +INF | . |
| ACT32.SEN1.MSOFCHINA | . | 0.100 | +INF | . |
| ACT32.SEN1.MMRCIRAQ | 3.000 | 4.750 | +INF | . |
| ACT32.SEN1.MMPESERBIA | . | 0.100 | +INF | . |
| ACT32.SEN2.MMPESERBIA | . | 0.050 | +INF | . |
| ACT32.SEN2.MSOF | . | 0.050 | +INF | . |
| ACT32.SEN2.MMRCCHINA | 3.000 | 3.700 | +INF | . |
| ACT33.SEN1.MSOFCHINA | . | 0.400 | +INF | . |
| ACT33.SEN1.MMRCIRAQ | 1.000 | 6.200 | +INF | . |
| ACT33.SEN1.MMPESERBIA | . | 1.000 | +INF | . |

| | | | | |
|---|---|---|---|---|
| ACT33.SEN2.MMPESERBIA | . | 0.500 | +INF | . |
| ACT33.SEN2.MSOF | . | 0.700 | +INF | . |
| ACT33.SEN2.MMRCCHINA | 1.000 | 6.800 | +INF | . |
| ACT34.SEN1.MSOFCHINA | . | 0.900 | +INF | . |
| ACT34.SEN1.MMRCIRAQ | 0.500 | 10.000 | +INF | . |
| ACT34.SEN1.MMPESERBIA | . | 1.700 | +INF | . |
| ACT34.SEN2.MMPESERBIA | . | 1.100 | +INF | . |
| ACT34.SEN2.MSOF | . | 1.300 | +INF | . |
| ACT34.SEN2.MMRCCHINA | 0.500 | 9.900 | +INF | . |
| ACT35.SEN1.MSOFCHINA | . | 1.400 | +INF | . |
| ACT35.SEN1.MMRCIRAQ | 5.000 | 15.100 | +INF | . |
| ACT35.SEN1.MMPESERBIA | . | 1.600 | +INF | . |
| ACT35.SEN2.MMPESERBIA | . | 0.800 | +INF | . |
| ACT35.SEN2.MSOF | . | 1.500 | +INF | . |
| ACT35.SEN2.MMRCCHINA | 20.000 | 20.200 | +INF | . |
| ACT36.SEN1.MSOFCHINA | . | 1.600 | +INF | . |
| ACT36.SEN1.MMRCIRAQ | 1.000 | 6.400 | +INF | . |
| ACT36.SEN1.MMPESERBIA | . | 2.000 | +INF | . |

EQU ASS sum of actions of units assigned to mission must be

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| ACT36.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT36.SEN2.MSOF | . | 1.800 | +INF | . |
| ACT36.SEN2.MMRCCHINA | 4.000 | 8.800 | +INF | . |
| ACT37.SEN1.MSOFCHINA | . | 0.800 | +INF | . |
| ACT37.SEN1.MMRCIRAQ | 1.000 | 3.400 | +INF | . |
| ACT37.SEN1.MMPESERBIA | . | 2.000 | +INF | . |
| ACT37.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT37.SEN2.MSOF | . | 1.400 | +INF | . |
| ACT37.SEN2.MMRCCHINA | 4.000 | 4.600 | +INF | . |
| ACT38.SEN1.MSOFCHINA | . | 2.000 | +INF | . |
| ACT38.SEN1.MMRCIRAQ | 1.000 | 1.000 | +INF | EPS |
| ACT38.SEN1.MMPESERBIA | . | 1.000 | +INF | . |
| ACT38.SEN2.MMPESERBIA | . | 0.500 | +INF | . |
| ACT38.SEN2.MSOF | . | 1.500 | +INF | . |
| ACT38.SEN2.MMRCCHINA | 2.000 | 4.000 | +INF | . |
| ACT39.SEN1.MSOFCHINA | . | 0.400 | +INF | . |
| ACT39.SEN1.MMRCIRAQ | 1.000 | 3.600 | +INF | . |
| ACT39.SEN1.MMPESERBIA | . | 2.000 | +INF | . |
| ACT39.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT39.SEN2.MSOF | . | 1.400 | +INF | . |

| | | | | |
|---|---|---|---|---|
| ACT39.SEN2.MMRCCHINA | 3.000 | 4.000 | +INF | . |
| ACT40.SEN1.MSOFCHINA | . | 3.000 | +INF | . |
| ACT40.SEN1.MMRCIRAQ | 1.000 | 5.000 | +INF | . |
| ACT40.SEN1.MMPESERBIA | . | 1.000 | +INF | . |
| ACT40.SEN2.MMPESERBIA | . | . | +INF | . |
| ACT40.SEN2.MSOF | . | 1.000 | +INF | . |
| ACT40.SEN2.MMRCCHINA | 10.000 | 10.000 | +INF | 5920.000 |
| ACT41.SEN1.MSOFCHINA | . | 1.600 | +INF | . |
| ACT41.SEN1.MMRCIRAQ | 1.000 | 6.400 | +INF | . |
| ACT41.SEN1.MMPESERBIA | . | 2.000 | +INF | . |
| ACT41.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT41.SEN2.MSOF | . | 1.800 | +INF | . |
| ACT41.SEN2.MMRCCHINA | 2.000 | 8.800 | +INF | . |
| ACT42.SEN1.MSOFCHINA | . | 1.100 | +INF | . |
| ACT42.SEN1.MMRCIRAQ | 0.500 | 4.600 | +INF | . |
| ACT42.SEN1.MMPESERBIA | . | 2.300 | +INF | . |
| ACT42.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT42.SEN2.MSOF | . | 1.400 | +INF | . |
| ACT42.SEN2.MMRCCHINA | 1.000 | 6.400 | +INF | . |
| ACT43.SEN1.MSOFCHINA | . | 2.100 | +INF | . |
| ACT43.SEN1.MMRCIRAQ | 0.500 | 1.400 | +INF | . |
| ACT43.SEN1.MMPESERBIA | . | 1.100 | +INF | . |
| ACT43.SEN2.MMPESERBIA | . | 0.500 | +INF | . |
| ACT43.SEN2.MSOF | . | 1.500 | +INF | . |
| ACT43.SEN2.MMRCCHINA | 1.000 | 4.600 | +INF | . |
| ACT44.SEN1.MSOFCHINA | . | 0.400 | +INF | . |
| ACT44.SEN1.MMRCIRAQ | 0.500 | 3.600 | +INF | . |
| ACT44.SEN1.MMPESERBIA | . | 2.000 | +INF | . |
| ACT44.SEN2.MMPESERBIA | . | 1.000 | +INF | . |

EQU ASS sum of actions of units assigned to mission must be

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| ACT44.SEN2.MSOF | . | 1.400 | +INF | . |
| ACT44.SEN2.MMRCCHINA | 1.000 | 4.000 | +INF | . |
| ACT45.SEN1.MSOFCHINA | . | 0.500 | +INF | . |
| ACT45.SEN1.MMRCIRAQ | 0.300 | 5.500 | +INF | . |
| ACT45.SEN1.MMPESERBIA | . | 0.900 | +INF | . |
| ACT45.SEN2.MMPESERBIA | . | 0.700 | +INF | . |
| ACT45.SEN2.MSOF | . | 0.800 | +INF | . |
| ACT45.SEN2.MMRCCHINA | 1.000 | 4.900 | +INF | . |
| ACT46.SEN1.MSOFCHINA | . | 0.600 | +INF | . |

| | | | | |
|---|---|---|---|---|
| ACT46.SEN1.MMRCIRAQ | 0.500 | 3.700 | +INF | . |
| ACT46.SEN1.MMPESERBIA | . | 0.600 | +INF | . |
| ACT46.SEN2.MMPESERBIA | . | 0.300 | +INF | . |
| ACT46.SEN2.MSOF | . | 0.300 | +INF | . |
| ACT46.SEN2.MMRCCHINA | 2.000 | 3.800 | +INF | . |
| ACT47.SEN1.MSOFCHINA | . | 0.700 | +INF | . |
| ACT47.SEN1.MMRCIRAQ | 0.500 | 4.300 | +INF | . |
| ACT47.SEN1.MMPESERBIA | . | 0.700 | +INF | . |
| ACT47.SEN2.MMPESERBIA | . | 0.300 | +INF | . |
| ACT47.SEN2.MSOF | . | 0.300 | +INF | . |
| ACT47.SEN2.MMRCCHINA | 2.000 | 4.500 | +INF | . |
| ACT48.SEN1.MSOFCHINA | . | 0.400 | +INF | . |
| ACT48.SEN1.MMRCIRAQ | . | 6.400 | +INF | . |
| ACT48.SEN1.MMPESERBIA | 0.500 | 1.200 | +INF | . |
| ACT48.SEN2.MMPESERBIA | 0.500 | 0.600 | +INF | . |
| ACT48.SEN2.MSOF | . | 0.900 | +INF | . |
| ACT48.SEN2.MMRCCHINA | . | 6.900 | +INF | . |
| ACT49.SEN1.MSOFCHINA | . | 2.000 | +INF | . |
| ACT49.SEN1.MMRCIRAQ | . | 2.600 | +INF | . |
| ACT49.SEN1.MMPESERBIA | 0.500 | 2.000 | +INF | . |
| ACT49.SEN2.MMPESERBIA | 0.500 | 1.000 | +INF | . |
| ACT49.SEN2.MSOF | . | 2.000 | +INF | . |
| ACT49.SEN2.MMRCCHINA | . | 5.600 | +INF | . |
| ACT50.SEN1.MSOFCHINA | . | 0.500 | +INF | . |
| ACT50.SEN1.MMRCIRAQ | . | 6.100 | +INF | . |
| ACT50.SEN1.MMPESERBIA | 0.200 | 0.500 | +INF | . |
| ACT50.SEN2.MMPESERBIA | 0.200 | 1.000 | +INF | . |
| ACT50.SEN2.MSOF | . | 1.000 | +INF | . |
| ACT50.SEN2.MMRCCHINA | . | 3.550 | +INF | . |
| ACT51.SEN1.MSOFCHINA | . | 0.700 | +INF | . |
| ACT51.SEN1.MMRCIRAQ | . | 6.300 | +INF | . |
| ACT51.SEN1.MMPESERBIA | 0.200 | 0.700 | +INF | . |
| ACT51.SEN2.MMPESERBIA | 0.200 | 0.500 | +INF | . |
| ACT51.SEN2.MSOF | . | 0.500 | +INF | . |
| ACT51.SEN2.MMRCCHINA | . | 5.150 | +INF | . |
| ACT52.SEN1.MSOFCHINA | . | 0.500 | +INF | . |
| ACT52.SEN1.MMRCIRAQ | . | 6.100 | +INF | . |
| ACT52.SEN1.MMPESERBIA | 0.200 | 0.500 | +INF | . |
| ACT52.SEN2.MMPESERBIA | 0.200 | 1.000 | +INF | . |
| ACT52.SEN2.MSOF | . | 1.000 | +INF | . |

EQU ASS sum of actions of units assigned to mission must be

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| ACT52.SEN2.MMRCCHINA | . | 3.550 | +INF | . |
| ACT53.SEN1.MSOFCHINA | . | 0.700 | +INF | . |
| ACT53.SEN1.MMRCIRAQ | . | 6.300 | +INF | . |
| ACT53.SEN1.MMPESERBIA | 0.200 | 0.700 | +INF | . |
| ACT53.SEN2.MMPESERBIA | 0.200 | 0.500 | +INF | . |
| ACT53.SEN2.MSOF | . | 0.500 | +INF | . |
| ACT53.SEN2.MMRCCHINA | . | 5.150 | +INF | . |
| ACT54.SEN1.MSOFCHINA | . | 0.600 | +INF | . |
| ACT54.SEN1.MMRCIRAQ | . | 5.900 | +INF | . |
| ACT54.SEN1.MMPESERBIA | 0.200 | 1.200 | +INF | . |
| ACT54.SEN2.MMPESERBIA | 0.200 | 0.800 | +INF | . |
| ACT54.SEN2.MSOF | . | 1.100 | +INF | . |
| ACT54.SEN2.MMRCCHINA | . | 5.800 | +INF | . |
| ACT55.SEN1.MSOFCHINA | . | . | +INF | . |
| ACT55.SEN1.MMRCIRAQ | 1.000 | 1.000 | +INF | . |
| ACT55.SEN1.MMPESERBIA | . | . | +INF | . |
| ACT55.SEN2.MMPESERBIA | . | . | +INF | . |
| ACT55.SEN2.MSOF | . | . | +INF | . |
| ACT55.SEN2.MMRCCHINA | 1.000 | 1.000 | +INF | . |
| ACT56.SEN1.MSOFCHINA | . | . | +INF | . |
| ACT56.SEN1.MMRCIRAQ | . | . | +INF | . |
| ACT56.SEN1.MMPESERBIA | . | 2.000 | +INF | . |
| ACT56.SEN2.MMPESERBIA | . | 1.000 | +INF | . |
| ACT56.SEN2.MSOF | 1.000 | 1.000 | +INF | EPS |
| ACT56.SEN2.MMRCCHINA | . | . | +INF | . |
| ACT57.SEN1.MSOFCHINA | . | . | +INF | . |
| ACT57.SEN1.MMRCIRAQ | 4.000 | 4.000 | +INF | EPS |
| ACT57.SEN1.MMPESERBIA | . | . | +INF | . |
| ACT57.SEN2.MMPESERBIA | . | . | +INF | . |
| ACT57.SEN2.MSOF | . | . | +INF | . |
| ACT57.SEN2.MMRCCHINA | 4.000 | 4.000 | +INF | 200.000 |

---- EQU CAP don't go over the allowable number of units to assign

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| SEN1.AA | -INF | . | . | . |
| SEN1.LID | -INF | . | . | -2000.000 |
| SEN1.ACR | -INF | . | . | EPS |
| SEN1.MEF | -INF | . | . | EPS |
| SEN1.ASD | -INF | . | . | EPS |

| | | | | |
|---|---|---|---|---|
| SEN1.HD | -INF | . | . | -3000.000 |
| SEN1.CBG | -INF | . | . | EPS |
| SEN1.FDA | -INF | . | . | -2170.000 |
| SEN1.SAG | -INF | -2.000 | . | . |
| SEN1.SOF | -INF | . | . | EPS |
| SEN1.SUB | -INF | . | . | EPS |
| SEN1.HBW | -INF | . | . | -2820.000 |

EQU CAP don't go over the allowable number of units to assign

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| SEN1.RIEW | -INF | . | . | EPS |
| SEN1.MW | -INF | . | . | EPS |
| SEN1.AS | -INF | -3.000 | . | . |
| SEN2.AA | -INF | . | . | . |
| SEN2.LID | -INF | -1.000 | . | . |
| SEN2.ACR | -INF | . | . | EPS |
| SEN2.MEF | -INF | . | . | -3050.000 |
| SEN2.ASD | -INF | . | . | EPS |
| SEN2.HD | -INF | -1.000 | . | . |
| SEN2.CBG | -INF | . | . | EPS |
| SEN2.FDA | -INF | . | . | -180.000 |
| SEN2.SAG | -INF | . | . | -6100.000 |
| SEN2.SOF | -INF | -1.000 | . | . |
| SEN2.SUB | -INF | . | . | . |
| SEN2.HBW | -INF | . | . | -180.000 |
| SEN2.RIEW | -INF | . | . | -1800.000 |
| SEN2.MW | -INF | . | . | -200.000 |
| SEN2.AS | -INF | . | . | -950.000 |

---- EQU BCAP don't pay for more than you can take

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| AA | -INF | 1.000 | 1.000 | . |
| LID | -INF | 1.000 | 4.000 | . |
| ACR | -INF | . | 2.000 | . |
| MEF | -INF | 6.000 | 6.000 | . |
| ASD | -INF | . | 1.000 | . |
| HD | -INF | 3.000 | 4.000 | . |
| CBG | -INF | 2.000 | 10.000 | . |

| | | | | |
|---|---|---|---|---|
| FDA | -INF | 6.000 | 16.000 | . |
| SAG | -INF | 5.000 | 5.000 | -4600.000 |
| SOF | -INF | 4.000 | 10.000 | . |
| SUB | -INF | 24.000 | 25.000 | . |
| HBW | -INF | . | 2.000 | . |
| RIEW | -INF | 2.000 | 2.000 | . |
| MW | -INF | 4.000 | 5.000 | . |
| AS | -INF | 3.000 | 4.000 | . |

---- VAR X number of units U assigned to each mission M in scenario S

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| AA .SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| AA .SEN1.MMRCIRAQ | . | 1.000 | 100.000 | EPS |
| AA .SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| AA .SEN2.MMPESERBIA | . | . | 100.000 | EPS |

VAR X number of units U assigned to each mission M in scenario S

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| AA .SEN2.MSOF | . | . | 100.000 | EPS |
| AA .SEN2.MMRCCHINA | . | 1.000 | 100.000 | EPS |
| LID .SEN1.MSOFCHINA | . | . | 100.000 | 2000.000 |
| LID .SEN1.MMRCIRAQ | . | 1.000 | 100.000 | 2000.000 |
| LID .SEN1.MMPESERBIA | . | . | 100.000 | 2000.000 |
| LID .SEN2.MMPESERBIA | . | . | 100.000 | EPS |
| LID .SEN2.MSOF | . | . | 100.000 | EPS |
| LID .SEN2.MMRCCHINA | . | . | 100.000 | EPS |
| ACR .SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| ACR .SEN1.MMRCIRAQ | . | . | 100.000 | EPS |
| ACR .SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| ACR .SEN2.MMPESERBIA | . | . | 100.000 | EPS |
| ACR .SEN2.MSOF | . | . | 100.000 | EPS |
| ACR .SEN2.MMRCCHINA | . | . | 100.000 | EPS |
| MEF .SEN1.MSOFCHINA | . | 1.000 | 100.000 | EPS |
| MEF .SEN1.MMRCIRAQ | . | 4.000 | 100.000 | EPS |
| MEF .SEN1.MMPESERBIA | . | 1.000 | 100.000 | EPS |
| MEF .SEN2.MMPESERBIA | . | . | 100.000 | 3050.000 |
| MEF .SEN2.MSOF | . | . | 100.000 | EPS |
| MEF .SEN2.MMRCCHINA | . | 6.000 | 100.000 | -2870.000 |

| | | | | |
|---|---|---|---|---|
| ASD .SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| ASD .SEN1.MMRCIRAQ | . | . | 100.000 | EPS |
| ASD .SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| ASD .SEN2.MMPESERBIA | . | . | 100.000 | EPS |
| ASD .SEN2.MSOF | . | . | 100.000 | EPS |
| ASD .SEN2.MMRCCHINA | . | . | 100.000 | EPS |
| HD .SEN1.MSOFCHINA | . | . | 100.000 | 3000.000 |
| HD .SEN1.MMRCIRAQ | . | 3.000 | 100.000 | 3000.000 |
| HD .SEN1.MMPESERBIA | . | . | 100.000 | 3000.000 |
| HD .SEN2.MMPESERBIA | . | 1.000 | 100.000 | EPS |
| HD .SEN2.MSOF | . | 1.000 | 100.000 | EPS |
| HD .SEN2.MMRCCHINA | . | . | 100.000 | EPS |
| CBG .SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| CBG .SEN1.MMRCIRAQ | . | . | 100.000 | EPS |
| CBG .SEN1.MMPESERBIA | . | 2.000 | 100.000 | EPS |
| CBG .SEN2.MMPESERBIA | . | 1.000 | 100.000 | EPS |
| CBG .SEN2.MSOF | . | 1.000 | 100.000 | EPS |
| CBG .SEN2.MMRCCHINA | . | . | 100.000 | -180.000 |
| FDA .SEN1.MSOFCHINA | . | . | 100.000 | 2170.000 |
| FDA .SEN1.MMRCIRAQ | . | 6.000 | 100.000 | 2170.000 |
| FDA .SEN1.MMPESERBIA | . | . | 100.000 | 2170.000 |
| FDA .SEN2.MMPESERBIA | . | . | 100.000 | 180.000 |
| FDA .SEN2.MSOF | . | . | 100.000 | 180.000 |
| FDA .SEN2.MMRCCHINA | . | 6.000 | 100.000 | EPS |
| SAG .SEN1.MSOFCHINA | . | 2.000 | 100.000 | EPS |
| SAG .SEN1.MMRCIRAQ | . | 1.000 | 100.000 | EPS |
| SAG .SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| SAG .SEN2.MMPESERBIA | . | . | 100.000 | 6100.000 |
| SAG .SEN2.MSOF | . | 1.000 | 100.000 | EPS |

VAR X number of units U assigned to each mission M in scenario S

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| SAG .SEN2.MMRCCHINA | . | 4.000 | 100.000 | EPS |
| SOF .SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| SOF .SEN1.MMRCIRAQ | . | 4.000 | 100.000 | EPS |
| SOF .SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| SOF .SEN2.MMPESERBIA | . | . | 100.000 | EPS |
| SOF .SEN2.MSOF | . | . | 100.000 | EPS |
| SOF .SEN2.MMRCCHINA | . | 3.000 | 100.000 | EPS |
| SUB .SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| SUB .SEN1.MMRCIRAQ | . | 24.000 | 100.000 | EPS |

| | | | | |
|---|---|---|---|---|
| SUB .SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| SUB .SEN2.MMPESERBIA | . | . | 100.000 | EPS |
| SUB .SEN2.MSOF | . | . | 100.000 | EPS |
| SUB .SEN2.MMRCCHINA | . | 24.000 | 100.000 | EPS |
| HBW .SEN1.MSOFCHINA | . | . | 100.000 | 2820.000 |
| HBW .SEN1.MMRCIRAQ | . | . | 100.000 | 2820.000 |
| HBW .SEN1.MMPESERBIA | . | . | 100.000 | 2820.000 |
| HBW .SEN2.MMPESERBIA | . | . | 100.000 | 180.000 |
| HBW .SEN2.MSOF | . | . | 100.000 | 180.000 |
| HBW .SEN2.MMRCCHINA | . | . | 100.000 | EPS |
| RIEW.SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| RIEW.SEN1.MMRCIRAQ | . | 2.000 | 100.000 | EPS |
| RIEW.SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| RIEW.SEN2.MMPESERBIA | . | . | 100.000 | 1800.000 |
| RIEW.SEN2.MSOF | . | 1.000 | 100.000 | 1800.000 |
| RIEW.SEN2.MMRCCHINA | . | 1.000 | 100.000 | EPS |
| MW .SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| MW .SEN1.MMRCIRAQ | . | 4.000 | 100.000 | EPS |
| MW .SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| MW .SEN2.MMPESERBIA | . | . | 100.000 | 200.000 |
| MW .SEN2.MSOF | . | . | 100.000 | 200.000 |
| MW .SEN2.MMRCCHINA | . | 4.000 | 100.000 | EPS |
| AS .SEN1.MSOFCHINA | . | . | 100.000 | EPS |
| AS .SEN1.MMRCIRAQ | . | . | 100.000 | EPS |
| AS .SEN1.MMPESERBIA | . | . | 100.000 | EPS |
| AS .SEN2.MMPESERBIA | . | . | 100.000 | 950.000 |
| AS .SEN2.MSOF | . | . | 100.000 | 950.000 |
| AS .SEN2.MMRCCHINA | . | 3.000 | 100.000 | 950.000 |

---- VAR NU number of each unit picked

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| AA | . | 1.000 | 100.000 | 3250.000 |
| LID | . | 1.000 | 100.000 | EPS |
| ACR | . | . | 100.000 | 2050.000 |
| MEF | . | 6.000 | 100.000 | EPS |
| ASD | . | . | 100.000 | 3000.000 |
| HD | . | 3.000 | 100.000 | EPS |
| CBG | . | 2.000 | 100.000 | 3250.000 |
| FDA | . | 6.000 | 100.000 | EPS |
| SAG | . | 5.000 | 100.000 | EPS |

| | | | | |
|---|---|---|---|---|
| SOF | . | 4.000 | 100.000 | 230.000 |
| SUB | . | 24.000 | 100.000 | 250.000 |
| HBW | . | . | 100.000 | EPS |
| RIEW | . | 2.000 | 100.000 | EPS |
| MW | . | 4.000 | 100.000 | EPS |
| AS | . | 3.000 | 100.000 | EPS |

| | LOWER | LEVEL | UPPER | MARGINAL |
|---|---|---|---|---|
| ---- VAR TOTCOST | -INF | 74820.000 | +INF | . |

TOTCOST variable for the objective

**** REPORT SUMMARY : 0 NONOPT
0 INFEASIBLE
0 UNBOUNDED

EXECUTION TIME = 0.980 SECONDS VERID MW2-25-085